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Ito et al.

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(54) **ORGANIC LIGHT-EMITTING DEVICE**

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H01L 51/00 (2006.01)
H01L 51/50 (2006.01)

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(Continued)

(58) **Field of Classification Search**
CPC H01L 51/0072; H01L 51/0067
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,968,051 A 7/1976 Stamm et al.
6,582,837 B1 6/2003 Toguchi et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP 11-003782 A 1/1999
JP 2002-63989 2/2002
(Continued)

OTHER PUBLICATIONS

Patent Abstracts of Japan Publication No. JP 2009-224512, dated Oct. 1, 2009, for JP 5281304, 1 page.
(Continued)

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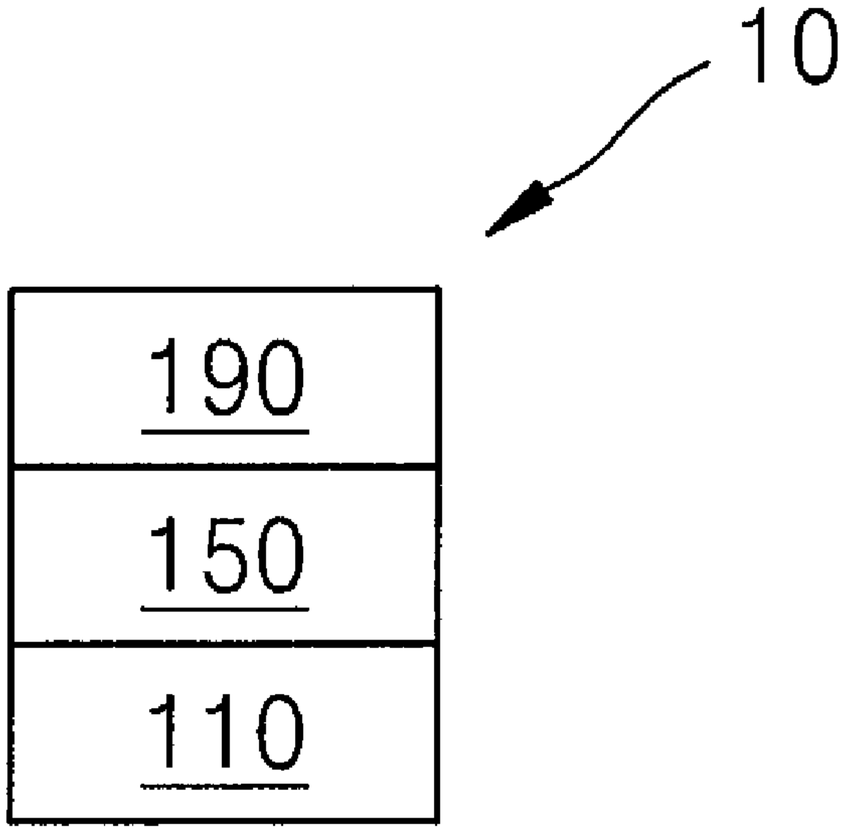
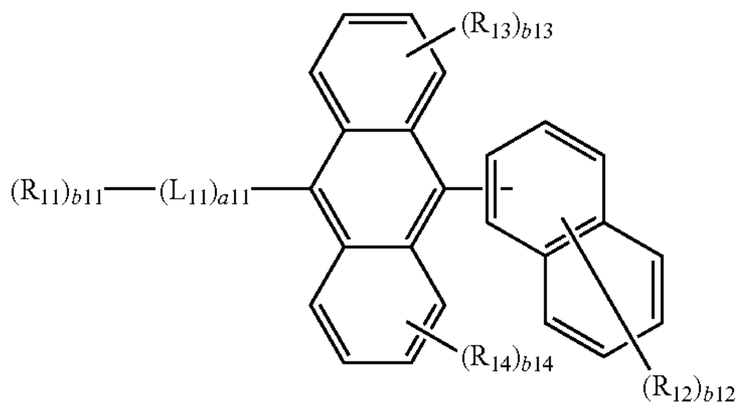
(57) **ABSTRACT**

An organic light-emitting device includes a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, wherein the organic layer includes at least one first material represented by Formula 1 below, and at least one second material represented by Formula 2 below:
(Continued)



Formula 1



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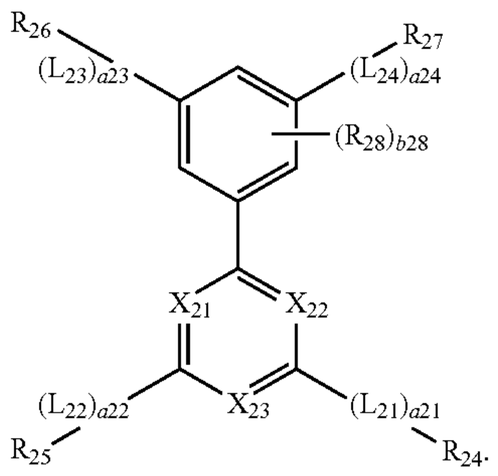

20 Claims, 1 Drawing Sheet

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(56) **References Cited**

U.S. PATENT DOCUMENTS

6,596,415	B2	7/2003	Shi et al.	
7,053,255	B2	5/2006	Ikeda et al.	
7,233,019	B2	6/2007	Ionkin et al.	
7,839,074	B2	11/2010	Ikeda et al.	
8,221,905	B2	7/2012	Lin et al.	
2004/0137270	A1	7/2004	Seo et al.	
2004/0214036	A1	10/2004	Bentsen et al.	
2005/0156164	A1	7/2005	Sotoyama	
2005/0214565	A1	9/2005	Ikeda et al.	
2005/0245752	A1	11/2005	Conley et al.	
2005/0249972	A1	11/2005	Hatwar et al.	
2006/0083945	A1	4/2006	Morishita et al.	
2006/0113905	A1	6/2006	Nakamura	
2006/0159952	A1	7/2006	Ricks et al.	
2007/0152565	A1	7/2007	Kubota et al.	
2007/0155991	A1	7/2007	Funahashi	
2007/0170419	A1	7/2007	Gerhard et al.	
2007/0237984	A1*	10/2007	Matsuura	C07C 13/567 428/690
2008/0160342	A1	7/2008	Meng et al.	
2008/0193796	A1	8/2008	Arakane et al.	
2009/0004458	A1	1/2009	Falster et al.	
2009/0004485	A1	1/2009	Zheng et al.	
2010/0013381	A1	1/2010	Stoessel et al.	
2010/0032658	A1	2/2010	Lee et al.	
2010/0052526	A1	3/2010	Je et al.	
2010/0187521	A1*	7/2010	Park	H01L 51/0058 257/40
2010/0244012	A1	9/2010	Mazur et al.	
2010/0270913	A1	10/2010	Matsuura et al.	
2010/0277061	A1	11/2010	Matsuura et al.	
2010/0279156	A1	11/2010	Kim et al.	
2010/0295445	A1	11/2010	Kuma et al.	
2011/0001130	A1	1/2011	Nishimura et al.	
2011/0006289	A1	1/2011	Mizuki et al.	
2011/0057116	A1	3/2011	Trogler et al.	
2011/0210320	A1*	9/2011	Shin	C07D 213/22 257/40
2011/0284832	A1	11/2011	In et al.	
2012/0001158	A1	1/2012	Asari et al.	
2012/0032152	A1	2/2012	Kim et al.	
2012/0056165	A1	3/2012	Kawamura et al.	
2012/0091885	A1	4/2012	Kim et al.	
2012/0138915	A1	6/2012	Nishimura et al.	
2012/0181518	A1	7/2012	Ogiwara et al.	
2012/0181922	A1	7/2012	Kawamura et al.	
2012/0235561	A1	9/2012	Ikeda et al.	
2012/0305904	A1	12/2012	Kai et al.	
2012/0313511	A1	12/2012	Tsurutani et al.	
2013/0049581	A1*	2/2013	Nishide	C09K 11/06 315/32
2013/0090446	A1*	4/2013	Zhou	C08G 61/123 528/8
2013/0105786	A1*	5/2013	Watanabe	C07C 49/665 257/40
2013/0112949	A1*	5/2013	Sim	H01L 51/5008 257/40
2013/0221332	A1*	8/2013	Xia	H01L 51/0035 257/40
2013/0295706	A1	11/2013	Goto et al.	
2013/0306958	A1	11/2013	Ito et al.	
2014/0008641	A1	1/2014	Kubota et al.	
2014/0048792	A1	2/2014	Chun et al.	
2014/0124763	A1	5/2014	Funahashi	
2014/0175395	A1*	6/2014	Kim	H01L 51/006 257/40
2014/0332772	A1*	11/2014	Han	H01L 51/0058 257/40
2014/0346464	A1*	11/2014	Kim	H01L 51/0058 257/40
2015/0001479	A1*	1/2015	Lee	H01L 51/0073 257/40
2015/0053946	A1*	2/2015	Kim	H01L 51/0094 257/40
2015/0069344	A1	3/2015	Kim et al.	
2015/0090964	A1*	4/2015	Hwang	H01L 51/0058 257/40
2015/0090965	A1*	4/2015	Park	H01L 51/0058 257/40
2015/0108448	A1*	4/2015	Dai	C09K 11/06 257/40
2015/0171337	A1	6/2015	Jung et al.	
2015/0236273	A1*	8/2015	Jang	H01L 51/0072 257/40
2015/0255736	A1	9/2015	Kim et al.	
2015/0318508	A1*	11/2015	Kim	H01L 51/5008 257/40
2015/0333266	A1*	11/2015	Ito	H01L 51/0052 257/40
2015/0349265	A1	12/2015	Hwang et al.	
2015/0357574	A1	12/2015	Ito et al.	
2015/0364693	A1	12/2015	Ito et al.	
2016/0005980	A1	1/2016	Ito et al.	
2016/0020404	A1	1/2016	Ito et al.	
2016/0133845	A1	5/2016	Jung et al.	

FOREIGN PATENT DOCUMENTS

JP	2003-306454		10/2003
JP	2005-041843	A	2/2005
JP	2006-273737	A	10/2006
JP	2008-291263		12/2008
JP	2009-212238		9/2009
JP	2012-82209		4/2012
JP	2012-156499	A	8/2012
JP	2013-063930		4/2013

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP	2013-063931	4/2013
JP	5281304	5/2013
JP	52-08271 B2	6/2013
KR	10-2005-0058465	6/2005
KR	10-2005-0086518	8/2005
KR	10-2005-0107809	11/2005
KR	10-2006-0006760	1/2006
KR	10-2006-0109524	10/2006
KR	10-2006-0113954	11/2006
KR	10-2006-0127138	12/2006
KR	10-2007-0009074	1/2007
KR	10-2007-0015195	2/2007
KR	10-2009-0033493	4/2009
KR	10-2010-0007552	1/2010
KR	10-2010-0007780	1/2010
KR	10-2010-0024894	3/2010
KR	10-2010-0048203	5/2010
KR	10-2010-0057465	5/2010
KR	10-2010-0070979	6/2010
KR	10-2010-0070992	6/2010
KR	10-2010-0093085	8/2010
KR	10-2010-0097182	9/2010
KR	10-2010-0099327	9/2010
KR	10-2010-0105099	9/2010
KR	10-2011-0015213	2/2011
KR	10-2011-0041728	4/2011
KR	10-2011-0094271	8/2011
KR	10-2011-0107679	10/2011
KR	10-2011-0134885	12/2011
KR	10-2012-0002865	1/2012
KR	10-2012-0026513	3/2012
KR	10-2012-0039470	4/2012
KR	10-2012-0041110	4/2012
KR	10-2012-0057611	6/2012
KR	10-2012-0066390	6/2012
KR	10-2012-0093354	8/2012
KR	10-2012-0117622	10/2012
KR	10-2012-0117675	10/2012
KR	10-2013-0007495	1/2013
KR	10-2013-0009765	1/2013
KR	10-1233377	2/2013
KR	10-1262420	5/2013
KR	10-2013-0100948	9/2013
WO	WO 2010/050781 A1	5/2010
WO	WO 2010/058995 A1	5/2010
WO	WO 2010/107244 A2	9/2010
WO	WO 2010/137678 A1	12/2010
WO	WO 2012/070226 A1	5/2012
WO	WO 2012/070234 A1	5/2012
WO	WO 2013/051875 A2	4/2013

OTHER PUBLICATIONS

Zhensheng Ding, et al., A Succinct Synthesis of the Vaulted Biaryl Ligand Vanol via a Dienone-Phenol Rearrangement, Full Papers, 2011 Wiley-VCH Verlag GmbH & Co., KGaA, Weinheim, Chem. Asian J. 2011, 6, 2130-2146, 17 pages.

USPTO Office Action for related U.S. Appl. No. 14/195,836, dated May 5, 2016, 18 pages.

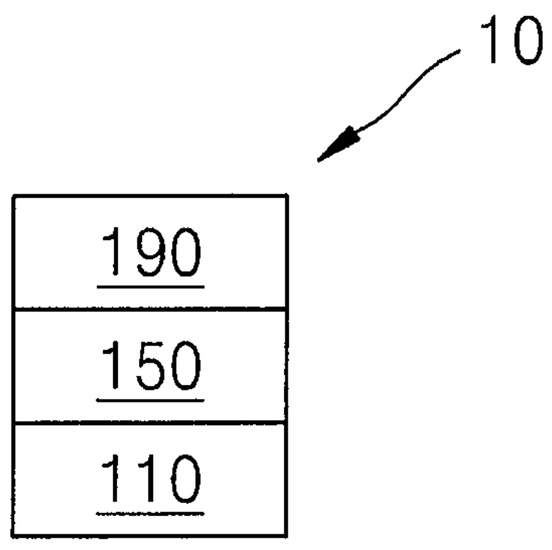
Katritzky, A., et al., *Polycyclic Fused Phenanthridines: An Alternative Approach from Benzotriazoles*, Center for Heterocyclic Compounds., Department of Chemistry, Univ. of Florida, pp. 1-27.

U.S. Office action dated Feb. 19, 2016, for cross reference U.S. Appl. No. 14/072,478, (12 pages).

U.S. Office action dated Oct. 6, 2016, for cross-referenced U.S. Appl. No. 14/550,801 (9 pages).

U.S. Office Action dated Apr. 20, 2016, issued in cross-reference U.S. Appl. No. 14/075,573 (10 pages).

* cited by examiner


10
190
150
110

ORGANIC LIGHT-EMITTING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Korean Patent Application No. 10-2014-0071076, filed on 11 Jun. 2014, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

One or more embodiments of the present invention relate to organic light-emitting devices.

2. Description of the Related Art

Organic light-emitting devices (OLEDs) are self-emitting devices that can provide multicolored images and have desired characteristics such as wide viewing angles, excellent contrast, quick response time, excellent brightness, low driving voltage, and excellent response speed.

An OLED has a structure including a first electrode disposed on a substrate, and a hole transport region, an emission layer (EML), an electron transport region, and a second electrode sequentially formed on the first electrode. Holes injected from the first electrode move to the EML via the hole transport region, and electrons injected from the second electrode move to the EML via the electron transport region. Thus, excitons are generated when carriers, such as holes and electrons, recombine in the EML. When the excitons drop from an excited state to a ground state, light is emitted.

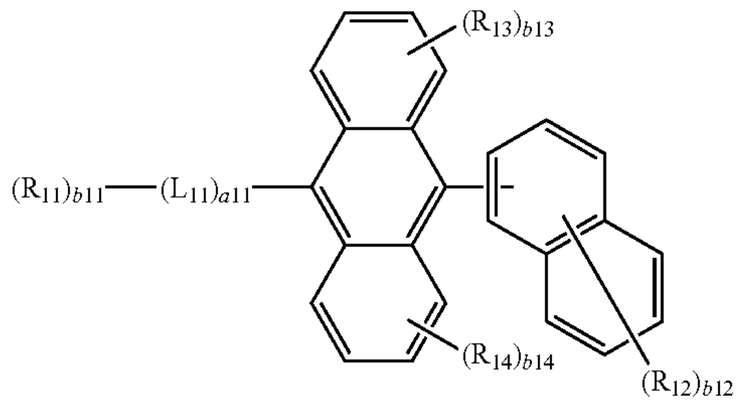
SUMMARY

One or more aspects according to one or more embodiments of the present invention are directed toward organic light-emitting devices.

Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

According to an embodiment of the present invention, an organic light-emitting device includes a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, wherein the organic layer includes at least one first material represented by Formula 1 below, and at least one second material represented by Formula 2 below:

Formula 1



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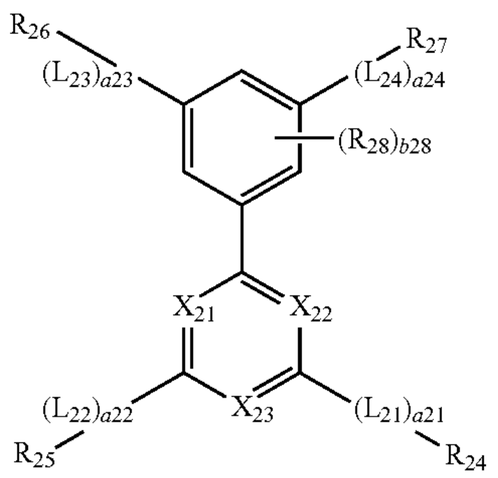
Formula 2



In Formulae 1 and 2,

X_{21} is CR_{21} or a nitrogen atom (N); X_{22} is CR_{22} or N; X_{23} is CR_{23} or N;

L_{11} and L_{21} to L_{24} are each independently selected from a substituted or unsubstituted C_6-C_{60} arylene group, and a substituted or unsubstituted C_1-C_{60} heteroarylene group;

a11 and a21 to a24 are each independently 0 or 1;

R_{11}, R_{12} and R_{24} to R_{27} are each independently selected from a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed hetero-polycyclic group;

b11 and b12 are each independently selected from 1, 2, and 3;

R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted. C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_1)(Q_2)(Q_3)$;

b13 and b14 are each independently selected from 1, 2, 3, and 4;

b28 is selected from 1, 2, and 3;

at least one substituent of the substituted C_6-C_{60} arylene group, substituted C_1-C_{60} heteroarylene group, substituted C_6-C_{60} aryl group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, substituted monovalent non-aromatic condensed hetero-polycyclic group, substituted C_1-C_{60} alkyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, and substituted C_6-C_{60} aryloxy group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted

with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{11})(Q_{12})(Q_{13})$;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_{31})(Q_{32})(Q_{33})$; wherein,

Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23} and Q_{31} to Q_{33} are each independently selected from a C_1-C_{60} alkyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group.

BRIEF DESCRIPTION OF THE DRAWING

These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawing in which the drawing shows a structure of an organic light-emitting device according to an embodiment of the present invention.

DETAILED DESCRIPTION

Reference will now be made in more detail to embodiments, examples of which are illustrated in the accompanying drawing, wherein like reference numerals refer to like elements throughout and repetitive descriptions thereof are omitted herein. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the FIGURE, to explain aspects of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

As the invention allows for various changes and numerous embodiments, example embodiments will be illustrated in the drawing and described in detail in the written description. The effects and properties of the present invention and methods of achieving the same will become clear with reference to the drawing and the embodiments described below. However, the present invention is not limited to the example embodiments set forth herein and may have various forms.

The terms used in the present specification are merely used to describe example embodiments, and are not intended to limit the present invention. An expression used in the singular encompasses the expression of the plural, unless it has a clearly different meaning in the context.

In the present specification, it is to be understood that the terms such as "including", "having", and "comprising" are intended to indicate the existence of the features, numbers, steps, actions, components, parts, or combinations thereof disclosed in the specification, and are not intended to preclude the possibility that one or more other features, numbers, steps, actions, components, parts, or combinations thereof may exist or may be added.

It will be understood that when a layer, region, or component is referred to as being "formed on" another layer, region, or component, it can be directly or indirectly formed on the other layer, region, or component. That is, for example, intervening layers, regions, or components may be present.

Sizes of components in the drawing may be exaggerated for convenience of explanation. In other words, since sizes and thicknesses of components in the drawing are arbitrarily illustrated for convenience of explanation, the following embodiments are not limited thereto.

As used herein, the expression an "(organic layer) includes at least one first material (represented by Formula 1)" may be construed as an "(organic layer) may include one first material (represented by Formula 1), or two or more different first materials (represented by Formula 1)".

As used herein, the expression, the "organic layer" is a term that refers to a single layer or a multi-layer disposed between the first electrode and the second electrode in the organic light-emitting device. Materials included in the "organic layer" are not limited to organic materials.

A substrate may be additionally disposed under the first electrode **110** or on the second electrode **190** in the drawing. The substrate may be a glass substrate or a transparent plastic substrate with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

The first electrode **110** may be formed by, for example, depositing or sputtering a material for the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for the first electrode **110** may be selected from materials with a high work function to enable ease of hole injection. The first electrode **110** may be a reflective electrode, a semi-transmission electrode, or a transmission electrode. The material for forming the first electrode **110** may be a transparent material with high conductivity, and examples of such a material are indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). To manufacture the first electrode **110**, which is a semi-transmission electrode or a transmission electrode, at least one of magnesium (Mg), aluminum (Al), aluminum-

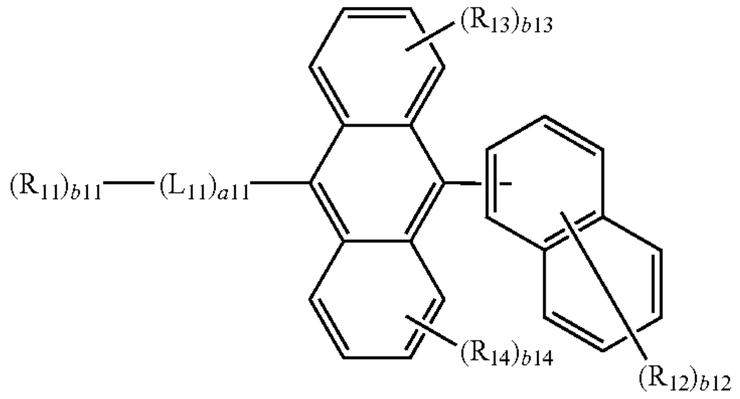
lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and the like may be used (utilized).

The first electrode **110** may have a single-layer structure or a multi-layer structure. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO, but is not limited thereto.

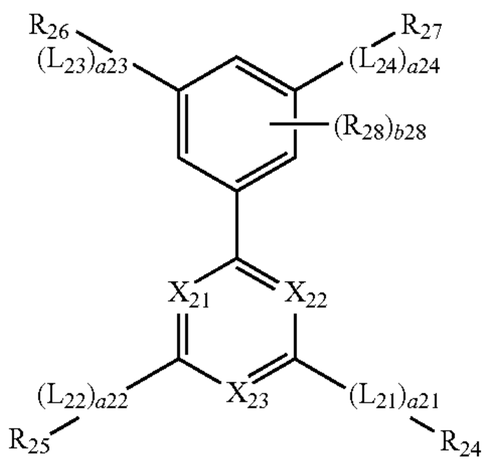
The organic layer **150** may be disposed on the first electrode **110**. The organic layer **150** includes an EML.

The organic layer **150** may include at least one first material represented by Formula 1 below, and at least one second material represented by Formula 2 below:

Formula 1



Formula 2



In Formulae 1 and 2,

X_{21} is CR_{21} or a nitrogen atom (N); X_{22} is CR_{22} or N; and X_{23} is CR_{23} or N;

L_{11}, and L_{21} to L_{24} are each independently selected from a substituted or unsubstituted C_6-C_{60} arylene group and a substituted or unsubstituted C_1-C_{60} heteroarylene group;

a11, and a21 to a24 are each independently 0 or 1;

R_{11}, R_{12}, and R_{24} to R_{27} are each independently selected from a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed hetero-polycyclic group;

b11 and b12 are each independently selected from 1, 2, and 3;

R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_1)(Q_2)(Q_3)$;

b13 and b14 are each independently selected from 1, 2, 3, and 4;

b28 is selected from 1, 2, and 3;

at least one substituent of the substituted C_6-C_{60} arylene group, substituted C_1-C_{60} heteroarylene group, substituted C_6-C_{60} aryl group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, substituted monovalent non-aromatic condensed hetero-polycyclic group, substituted C_1-C_{60} alkyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, and substituted C_6-C_{60} aryloxy group may be selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{11})(Q_{12})(Q_{13})$;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_{31})(Q_{32})(Q_{33})$; wherein

Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23} and Q_{31} to Q_{33} are each independently selected from a C_1-C_{60} alkyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-

aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group.

For example, in Formula 2, at least one of X_{21}, X_{22} and X_{23} may be N. In another embodiment, in Formula 2, X_{21} may be CR_{21}, X_{22} may be CR_{22}, and X_{23} may be N. In another embodiment, in Formula 2, X_{21} may be N, X_{22} may be N, and X_{23} may be CR_{23}. In another embodiment, in Formula 2, X_{21} may be N, X_{22} may be N, and X_{23} may be N.

For example, in Formulae 1 and 2, L_{11}, L_{21} to L_{24} are each independently selected from a phenylene group, a naphthylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an indolylene group, a quinolinylene group, a benzoquinolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a benzofuranylene group, a benzothiophenylene group, a triazolylene group, a tetrazolylene group, a triazinylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and

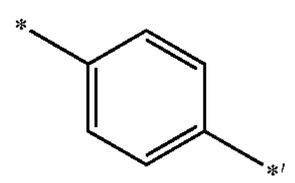
a phenylene group, a naphthylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an indolylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a benzofuranylene group, a benzothiophenylene group, a triazolylene group, a tetrazolylene group, a triazinylene group, a dibenzofuranylene group, and a dibenzothiophenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, and an imidazopyridinyl group, but they are not limited thereto.

In another embodiment, in Formulae 1 and 2, L_{11}, and L_{21} to L_{24} are each independently selected from a phenylene group, a naphthylene group, a pyridinylene group, a quinolinylene group, and an isoquinolinylene group; and

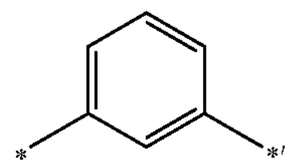
a phenylene group, a naphthylene group, a pyridinylene group, a quinolinylene group, and an isoquinolinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, and a naphthyl group, but they are not limited thereto.

In another embodiment, in Formulae 1 and 2, L_{11}, and L_{21} to L_{24} may be each independently groups selected from Formulae 3-1 to 3-6 below, but they are not limited thereto:

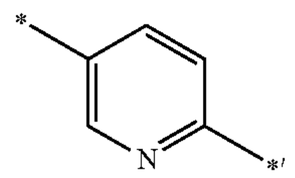
3-1



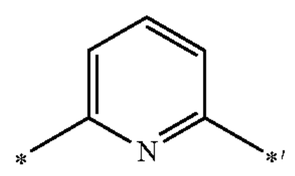
3-2



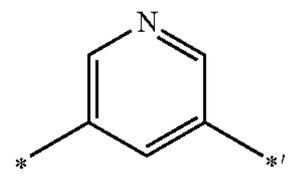
3-3



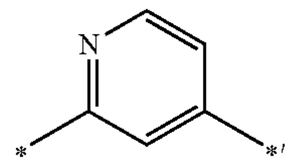
3-4



3-5



3-6



In Formulae 3-1 to 3-6,

* and *' are each a binding site to a neighboring atom.

In Formula 1, a11 represents the number of L_{11}s and when a11 is 0, $(L_{11})_{a11}$ may represent a direct bonding.

In Formula 1, a21 represents the number of L_{21}s and when a21 is 0, $(L_{21})_{a21}$ may represent a direct bonding.

In Formula 1, a22 represents the number of L_{22}s and when a22 is 0, $(L_{22})_{a22}$ may represent a direct bonding.

In Formula 1, a23 represents the number of L_{23}s and when a23 is 0, $(L_{23})_{a23}$ may represent a direct bonding.

In Formula 1, a24 represents the number of L_{24}s and when a24 is 0, $(L_{24})_{a24}$ may represent a direct bonding.

For example, in Formulae 1 and 2, R_{11}, R_{12} and R_{24} to R_{27} may be each independently selected from a phenyl group, a

pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, a naphthyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group.

In another embodiment, in Formulae 1 and 2, R_{11}, R_{12} and R_{24} to R_{27} may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, a naphthyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group.

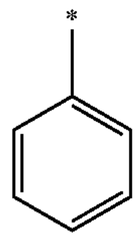
In another embodiment, in Formulae 1 and 2, R_{11}, R_{12} and R_{24} to R_{27} may be each independently selected from a

phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group; and

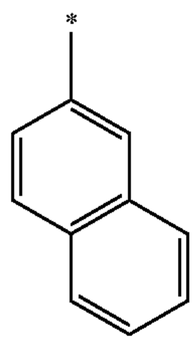
a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, a naphthyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group.

In another embodiment, in Formula 1, R_{11} and R_{12} may be each independently groups selected from Formulae 4-1 to 4-5, 4-23, and 4-24 below, but they are not limited thereto:

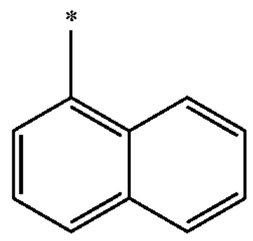
4-1



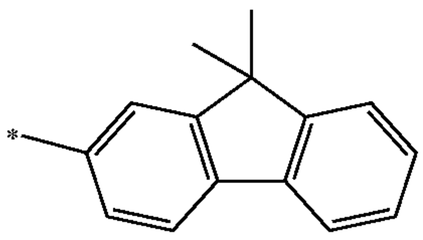
4-2



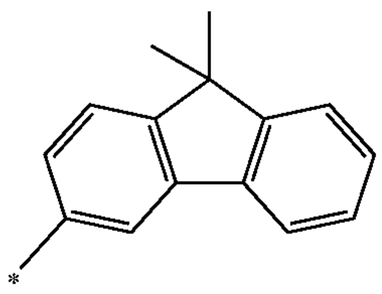
4-3



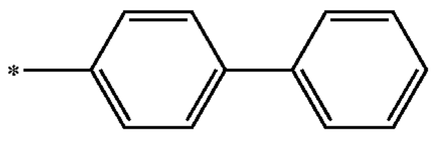
4-4



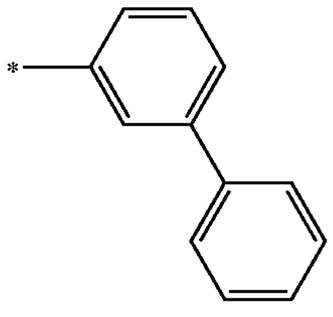
4-5



4-23



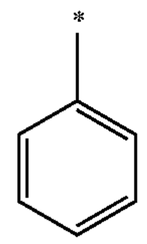
4-24



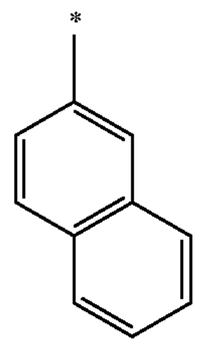
In Formulae 4-1 to 4-5, 4-23, and 4-24,
* is a binding site to a neighboring atom.

In another embodiment, in Formula 2, R_{24} to R_{27} may be each independently groups selected from Formulae 4-1 to 4-3 and 4-6 to 4-30 below, but they are not limited thereto:

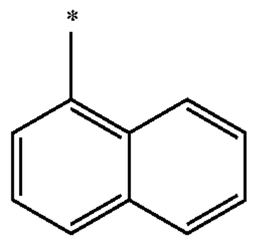
4-1



4-2



4-3



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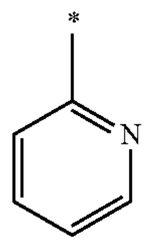
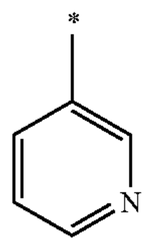
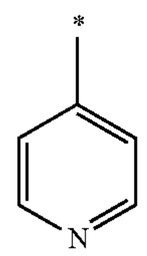


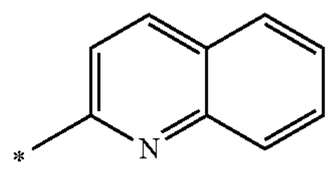
4-7



4-8



4-9



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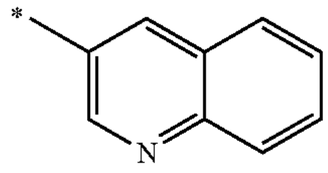

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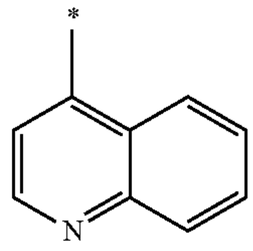

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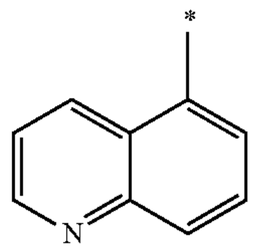

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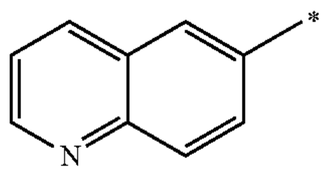

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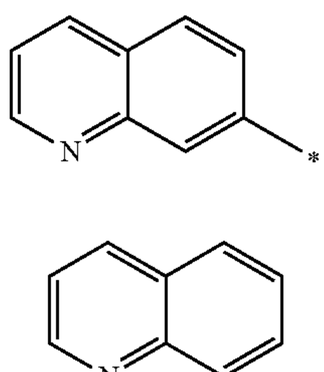

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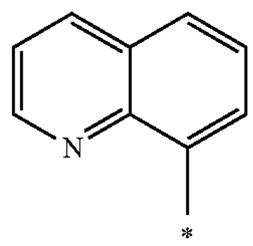

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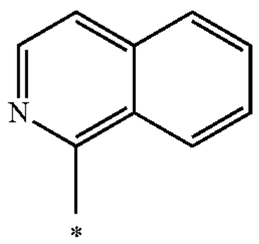
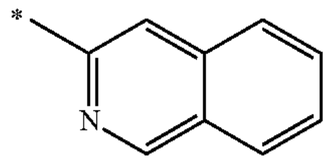
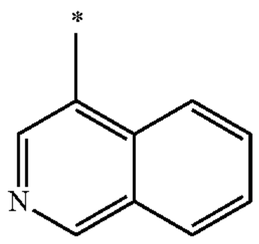


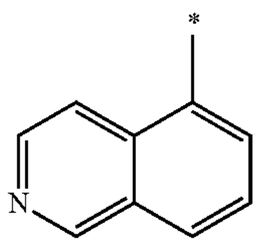
4-17



4-18



4-19



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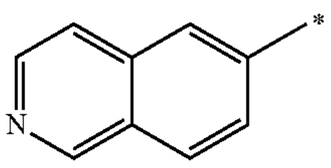

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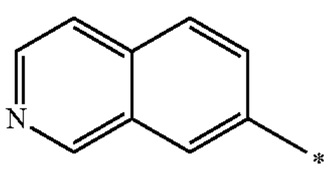

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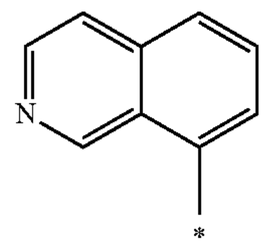

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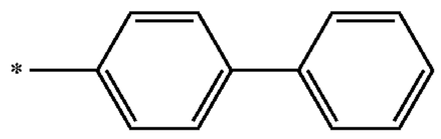
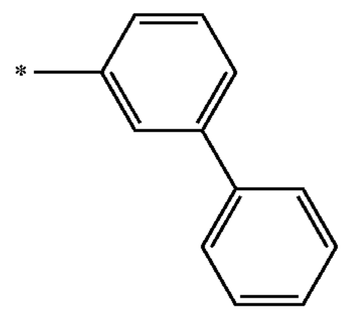
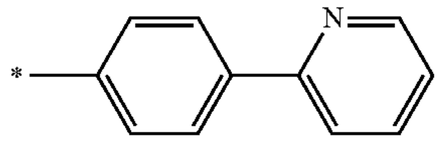


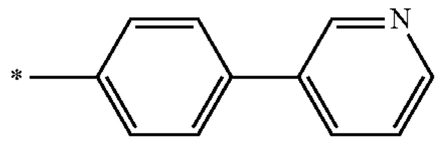
4-24



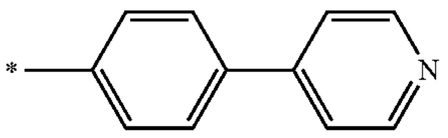
4-25



4-26



4-27



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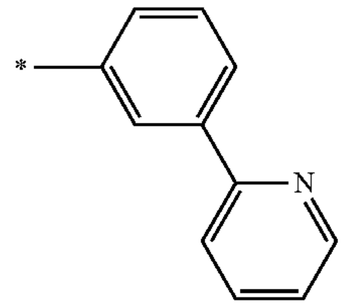
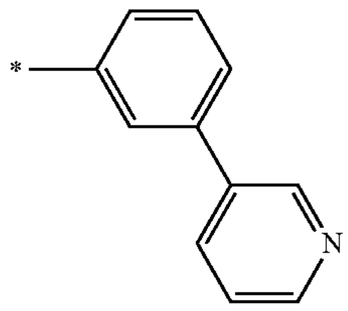
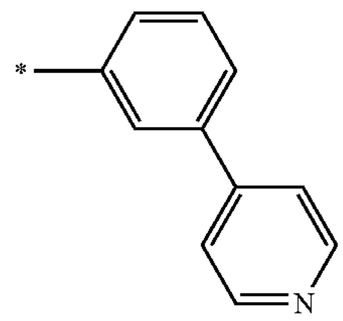


4-29



4-30



In Formulae 4-1 to 4-3 and 4-6 to 4-30,

* is a binding site to a neighboring atom.

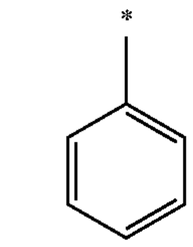
In Formulae 1 and 2, b11 and b12 may respectively represent the number of R_{11} and R_{12}, and when b11 and/or b12 is 2 or 3, a plurality of R_{11} and/or R_{12} may be the same as or different from each other.

For example, in Formulae 1 and 2, R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro

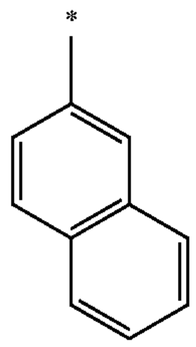
group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, an n-hexyl group, an n-heptyl group, an n-octyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, but they are not limited thereto.

In another embodiment, in Formulae 1 and 2, R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, an n-hexyl group, an n-heptyl group, an n-octyl group, and groups represented by Formulae 4-1 to 4-30 below, but they are not limited thereto:

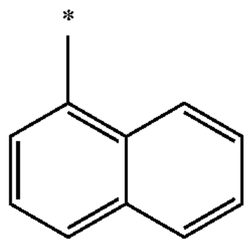
4-1



4-2



4-3



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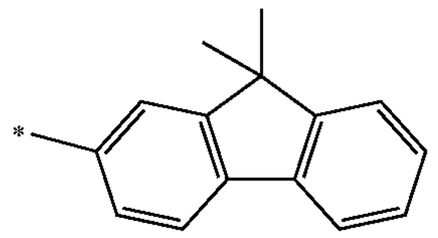
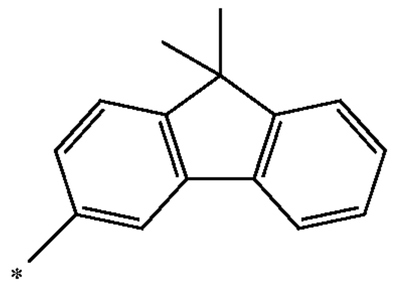
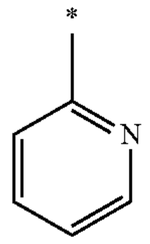
4-4



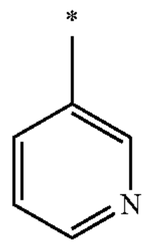
4-5



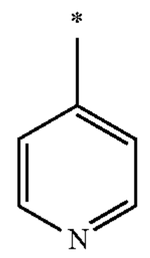
4-6



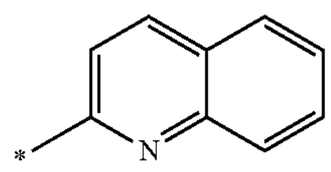
4-7



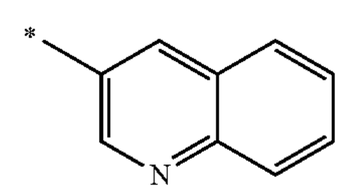
4-8



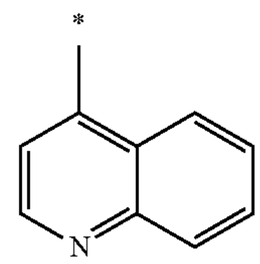
4-9



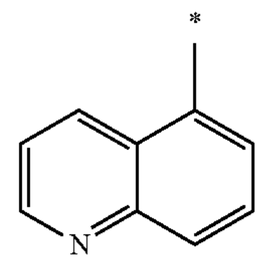
4-10



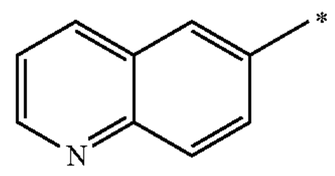
4-11



4-12



4-13



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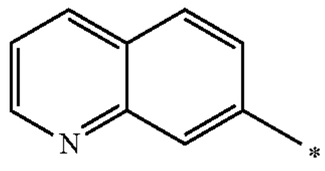
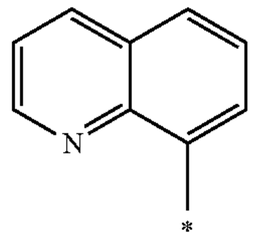
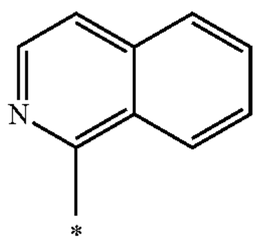
4-14



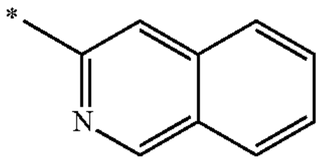
4-15



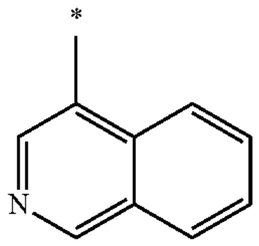
4-16



4-17



4-18



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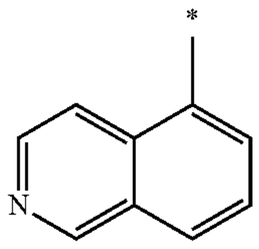

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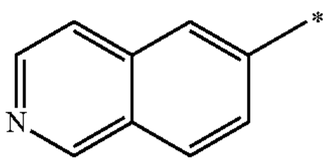
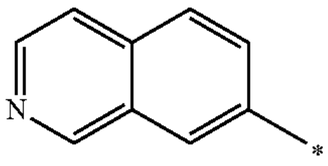
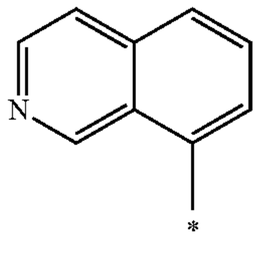


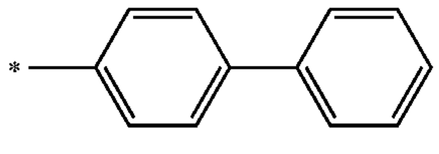
4-21



4-22



4-23



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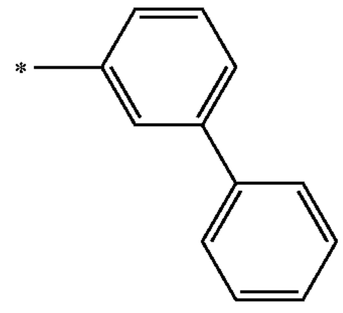
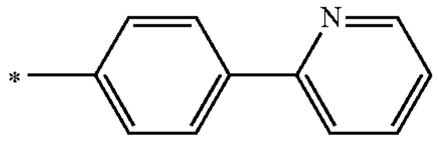
4-24



4-25



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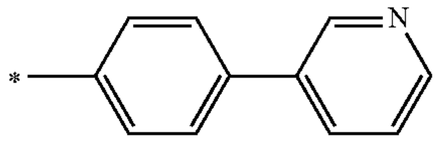

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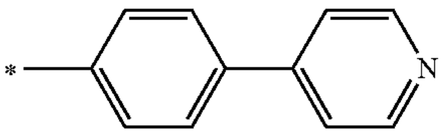
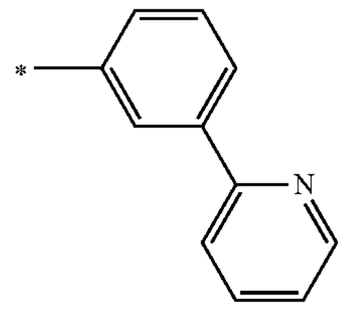
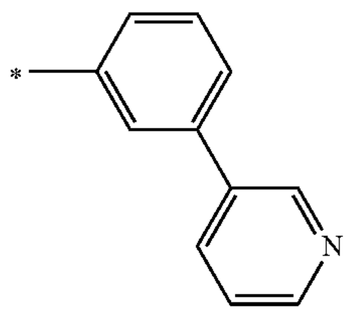


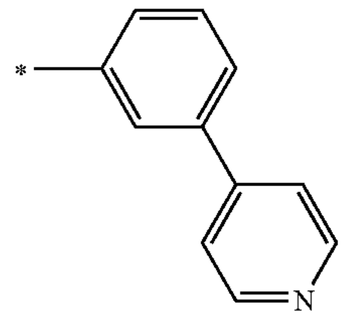
4-28



4-29



4-30



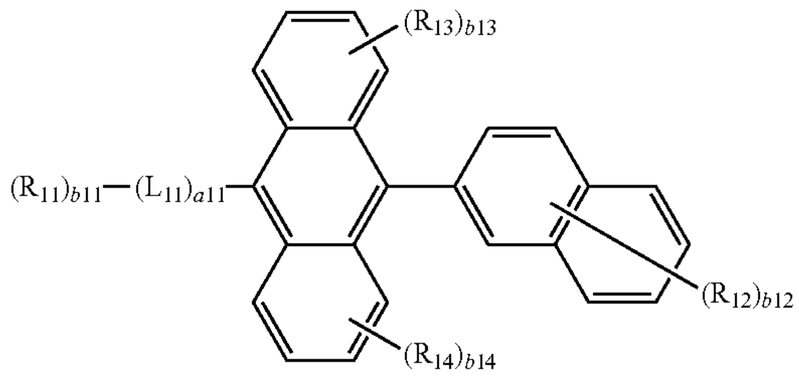
In Formulae 4-1 to 4-30,

* is a binding site to a neighboring atom.

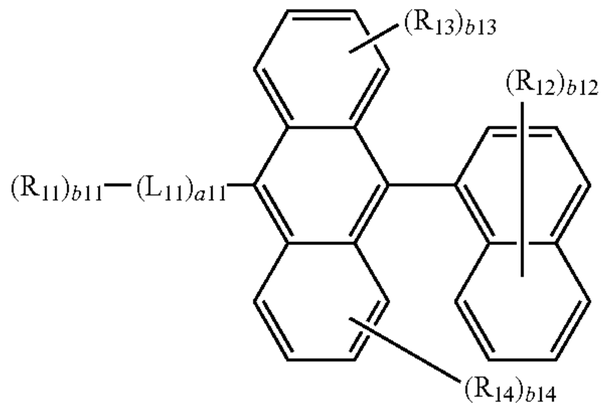
In Formulae 1 and 2, b13 and b14 may respectively represent the number of R_{13} and R_{14}, and when b13 and/or b14 is selected from 2, 3, and 4, a plurality of R_{13} and/or R_{14} may be the same as or different from each other.

For example, the first material may be represented by any one of Formulae 1A and 1B, and the second material may be represented by any one of Formulae 2A to 2C, but they are not limited thereto:

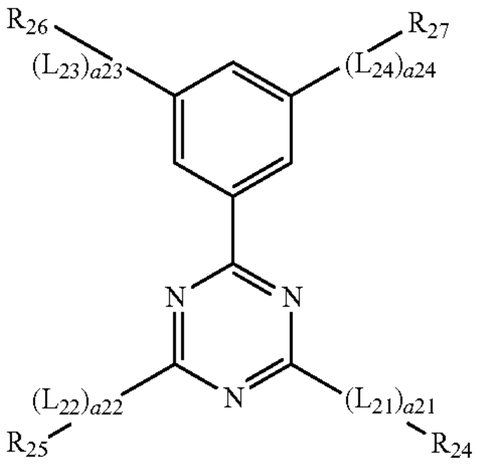
Formula 1A



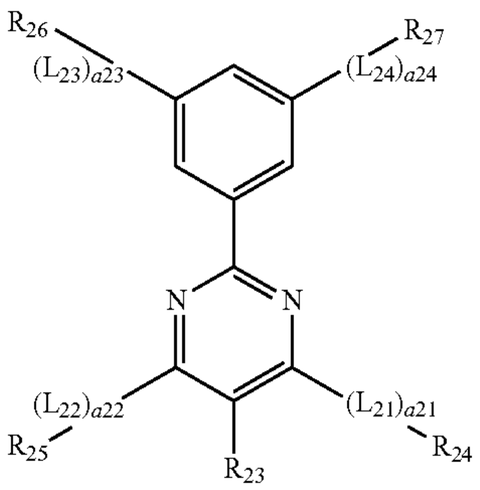
Formula 1B



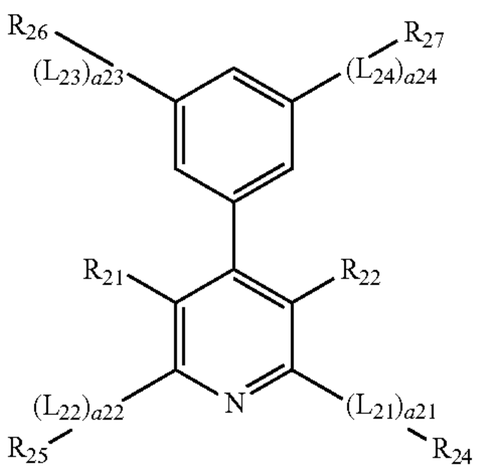
Formula 2A



Formula 2B



Formula 2C

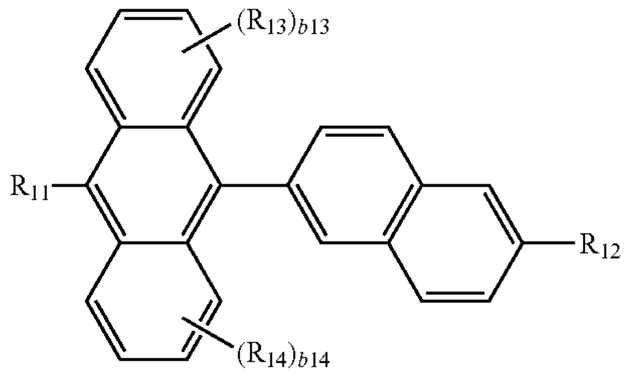


In Formulae 1A, 1B, 2A, 2B, and 2C,

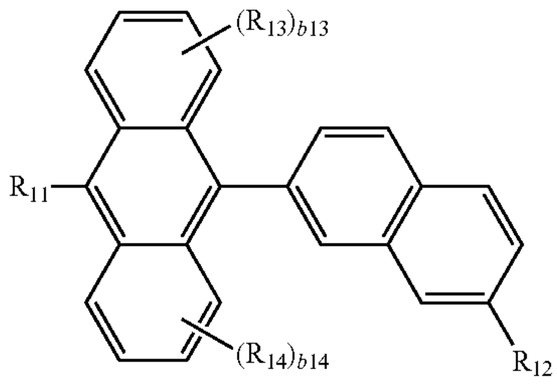
L_{11}, a11, R_{11} to R_{14}, b11 to b14, L_{21} to L_{24}, a21 to a24, and R_{21} to R_{27} are the same as described below.

In another embodiment, the first material may be represented by any one of Formulae 1A-1, 1A-2, 1B-1, and 1B-2 below, and the second material may be represented by any one of Formulae 2A to 2C below, but they are not limited thereto:

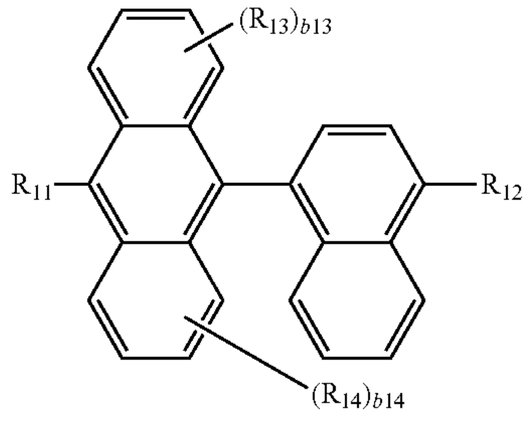
Formula 1A-1



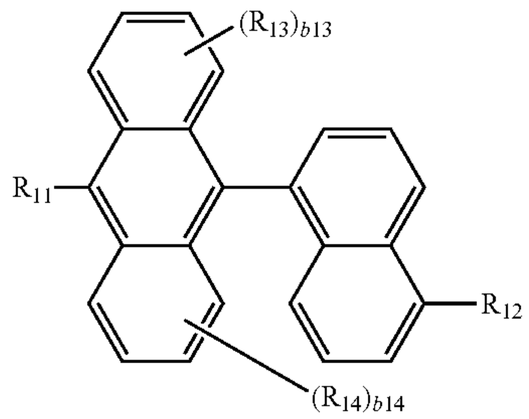
Formula 1A-2



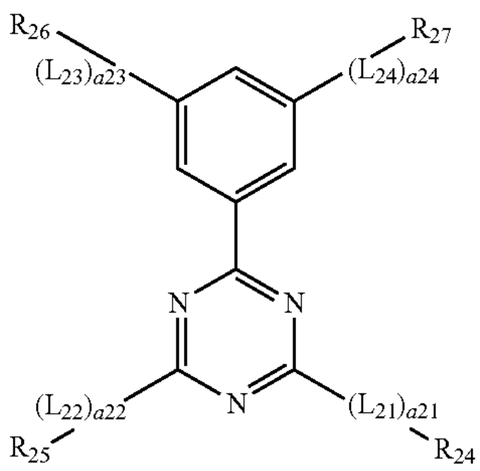
Formula 1B-1



Formula 1B-2



Formula 2A



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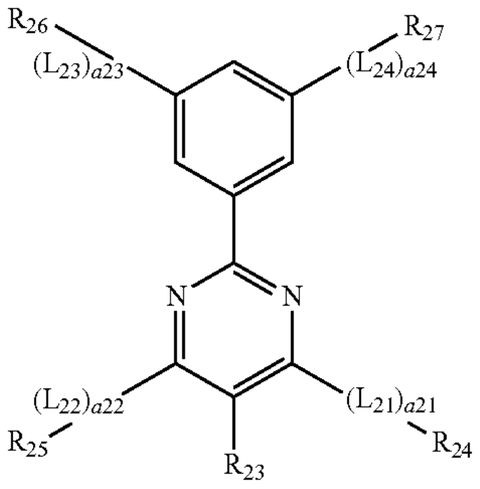
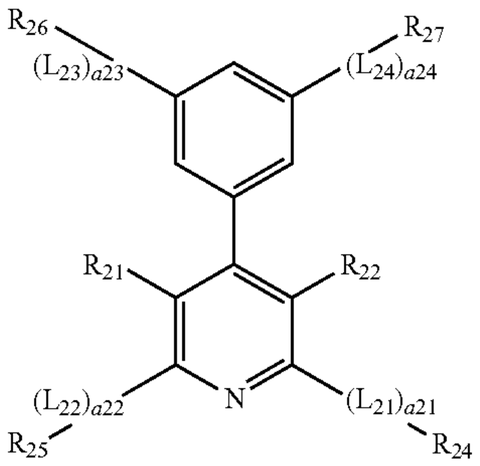
Formula 2B



Formula 2C

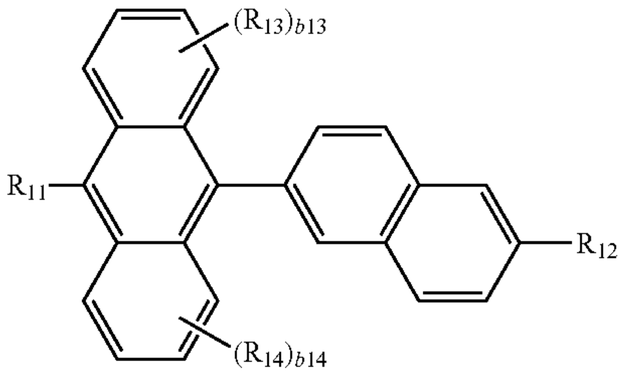


In Formula 1A-1, 1A-2, 1B-1, 1B-2, 2A, 2B and 2C,

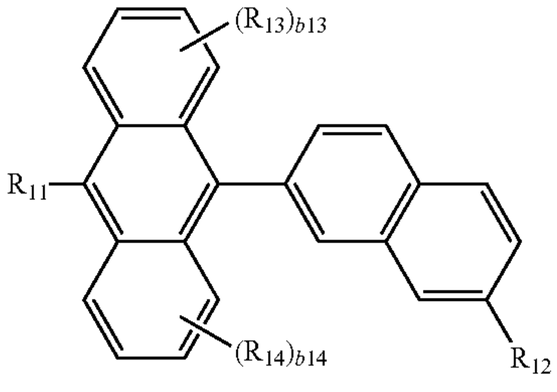
R_{11} to R_{14}, b13, b14, L_{21} to L_{24}, a21 to a24, and R_{21} to R_{27} are the same as described above.

In another embodiment, the first material may be represented by any one of Formulae 1A-1, 1A-2, 1B-1, and 1B-2 below, and the second material may be represented by any one of Formulae 2A-1 to 2C-1 below, but they are not limited thereto:

Formula 1A-1



Formula 1A-2



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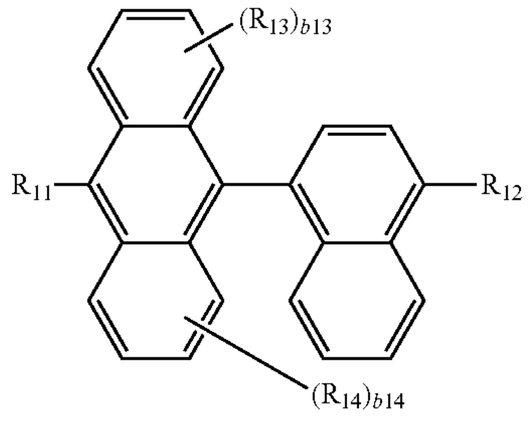
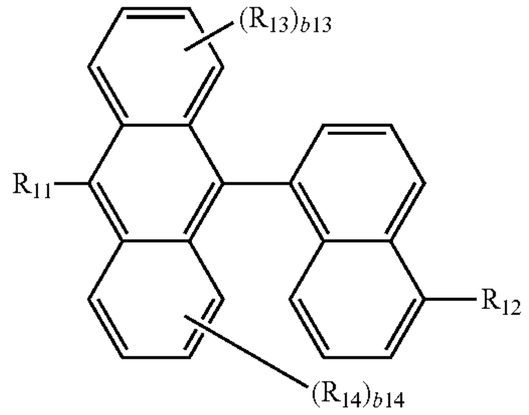
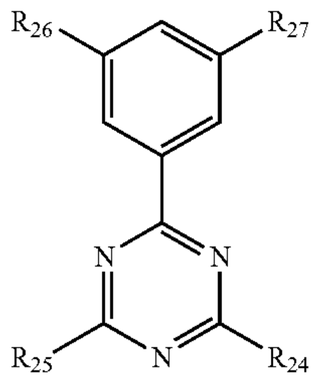
Formula 1B-1



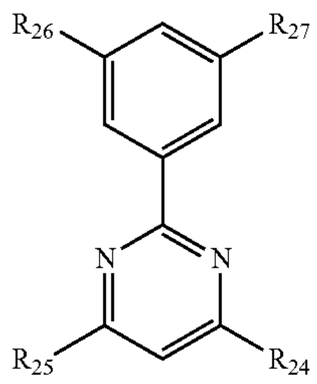
Formula 1B-2



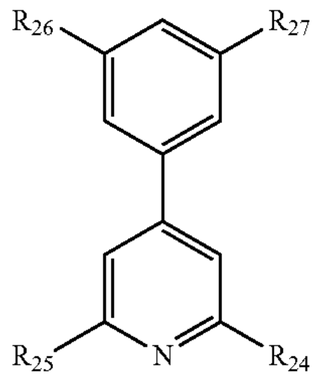
Formula 2A-1



Formula 2B-1



Formula 2C-1

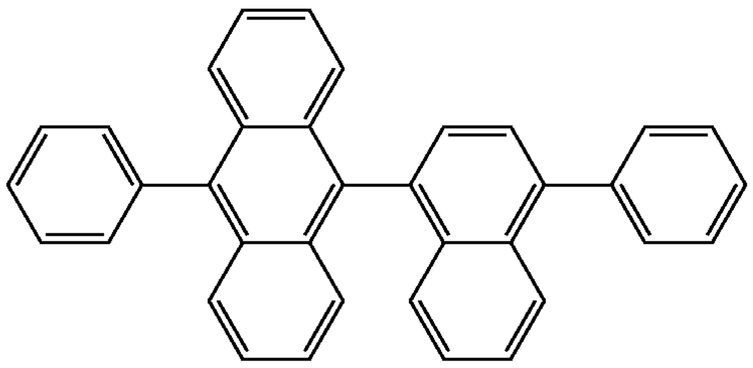


In Formula 1A-1, 1A-2, 1B-1, 1B-2, 2A-1, 2B-1, and 2C-1 above,

R_{11} to R_{14}, b13, b14, and R_{24} to R_{27} may be the same as described above.

In another embodiment, the first material may be selected from Compounds 100 to 201, and the second material may be selected from Compounds 300 to 544, but they are not limited thereto:

100



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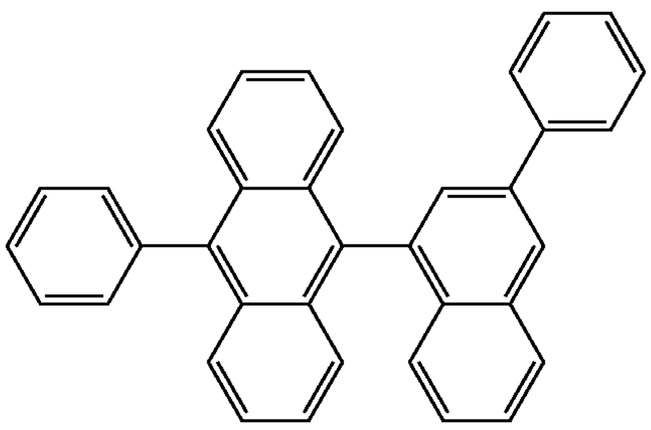
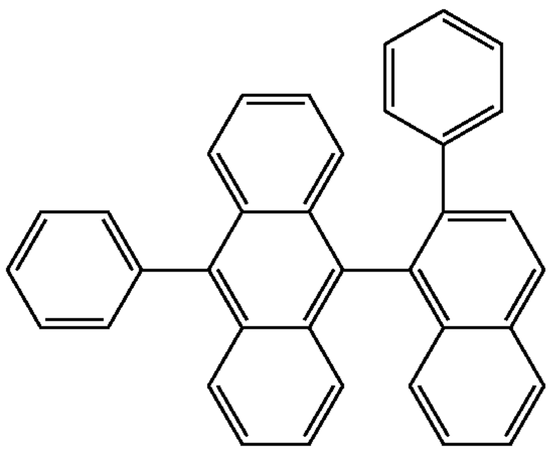
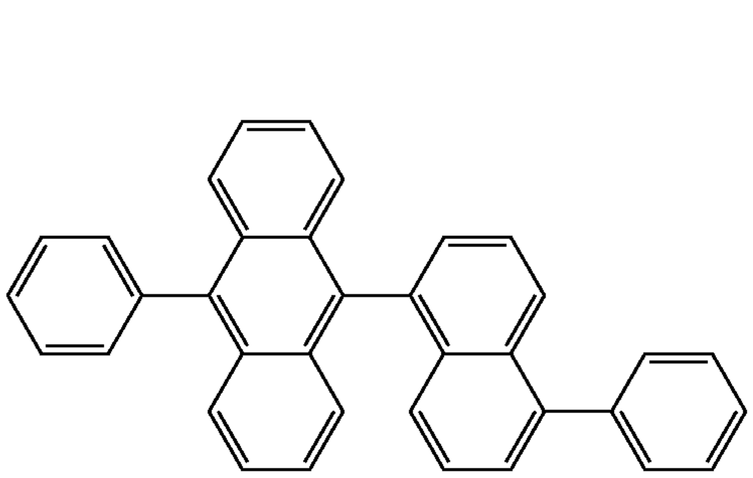


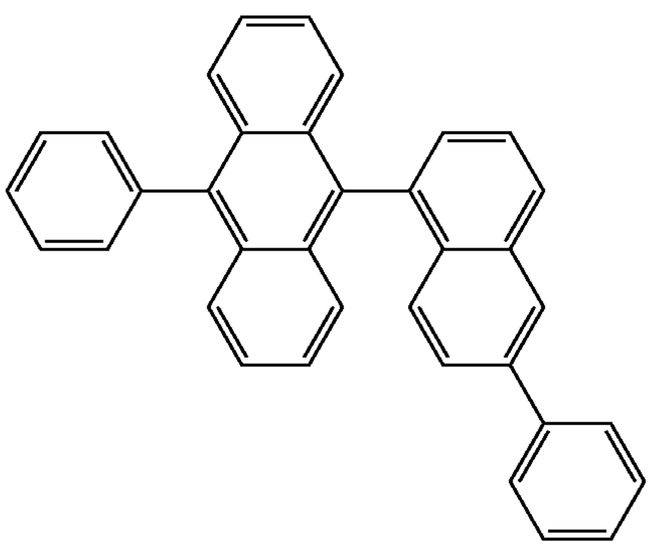
102



103



104



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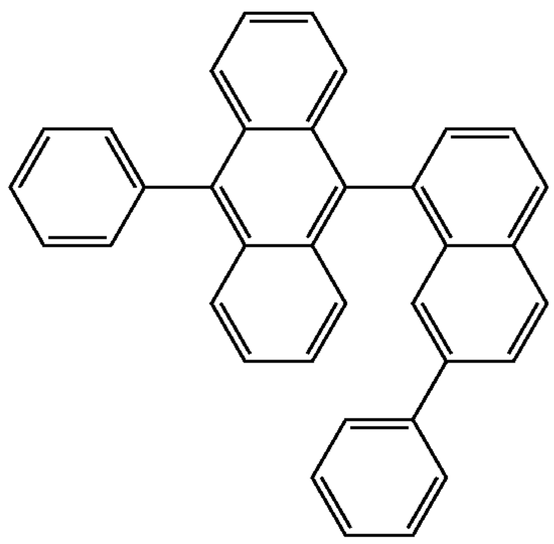
105



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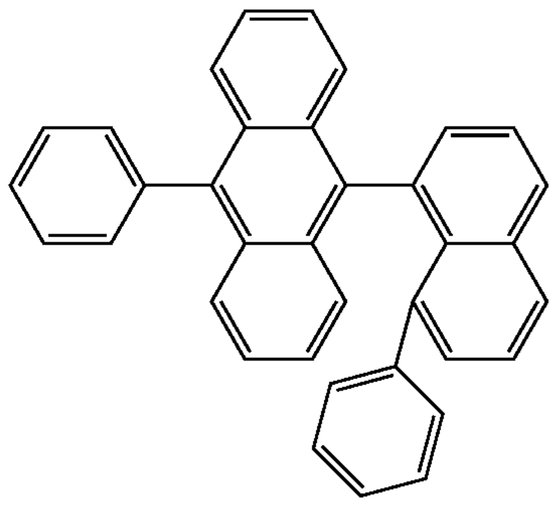
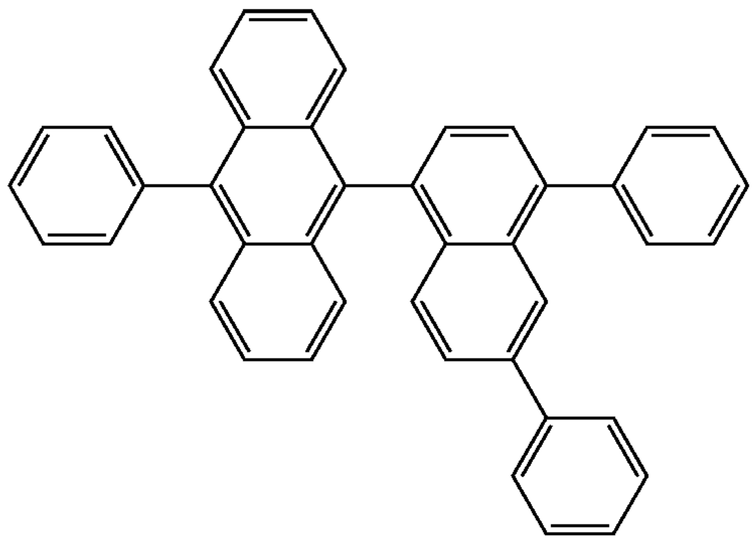


107



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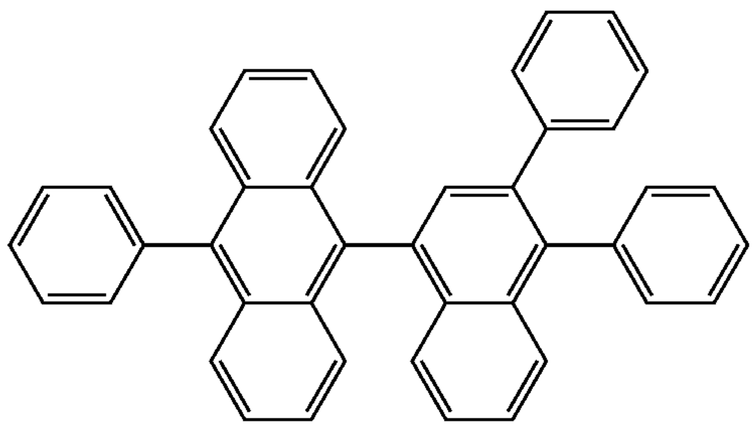

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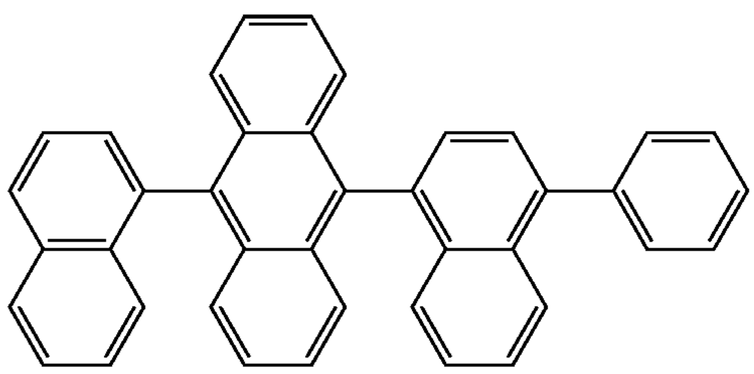

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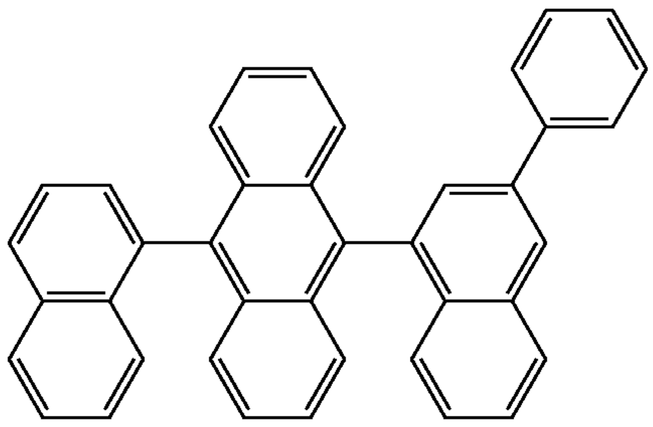
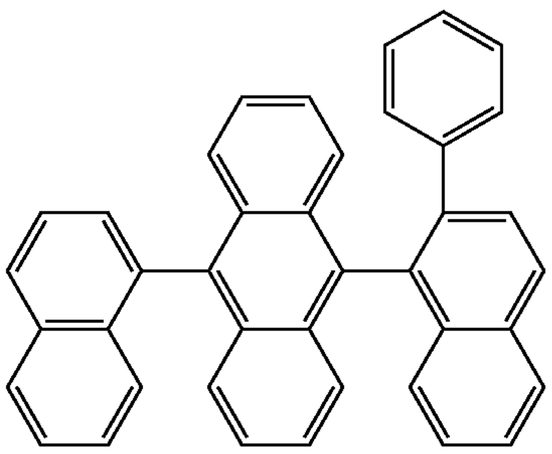
110



111



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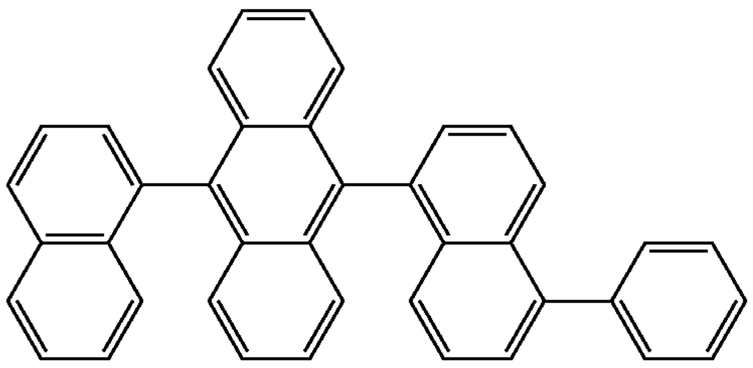
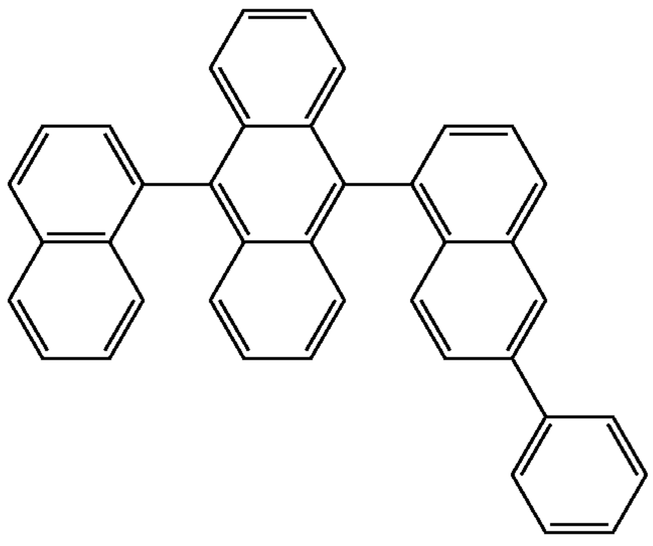


113



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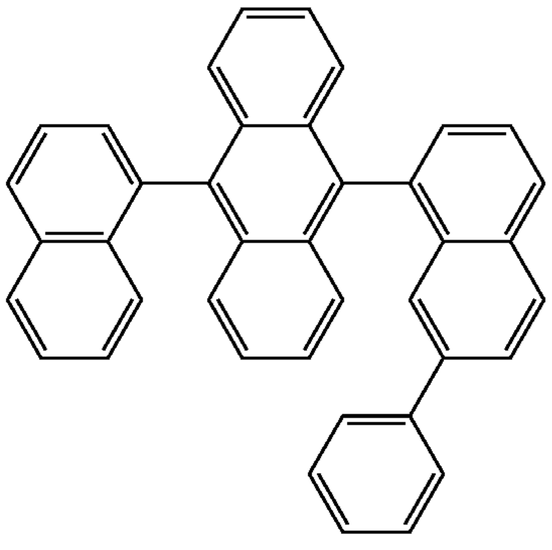

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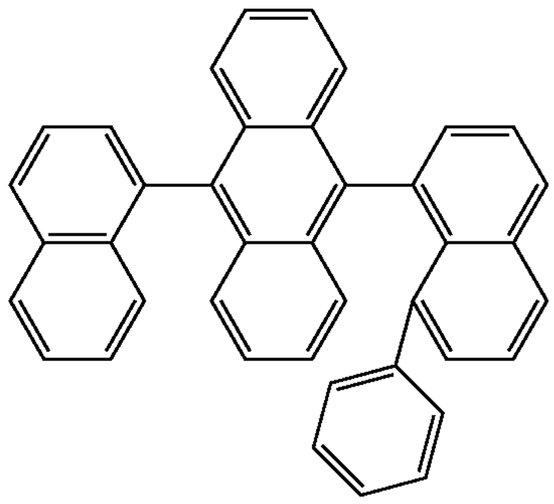
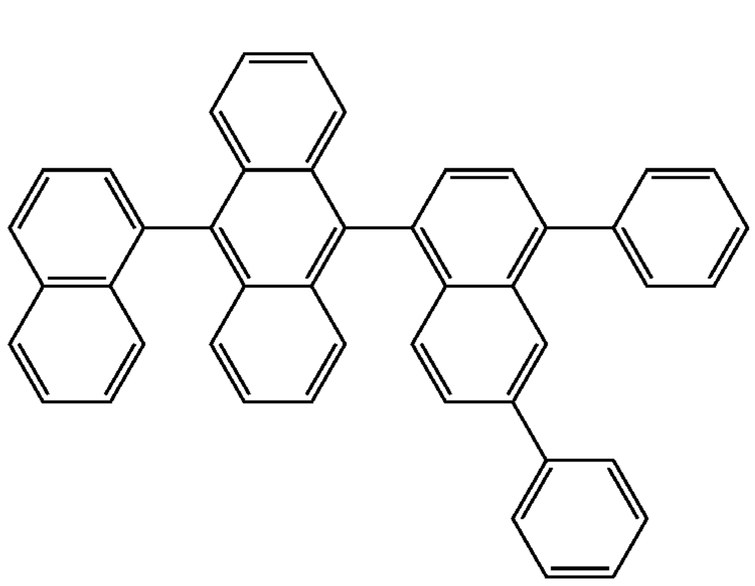
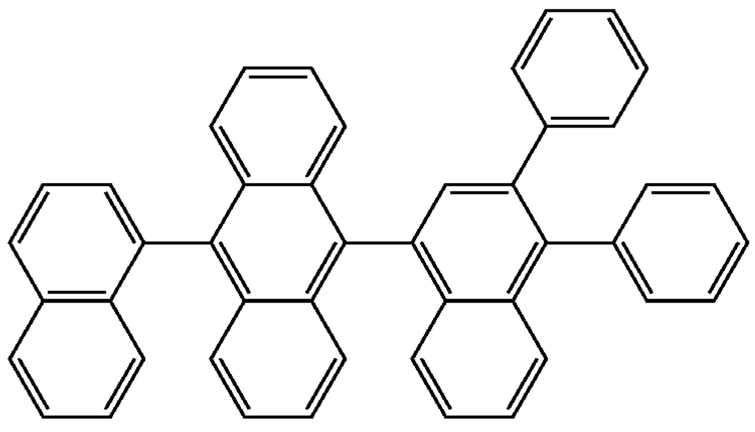
115



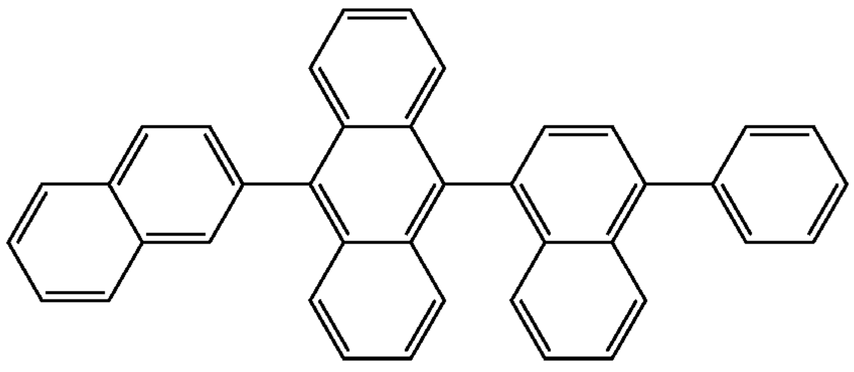
116



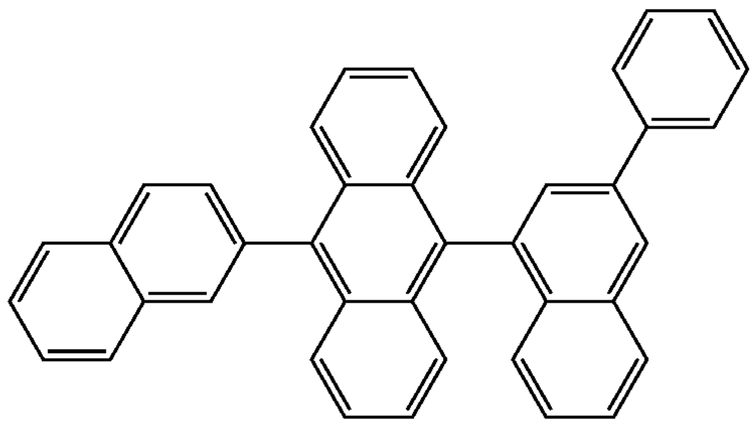
117



118



119



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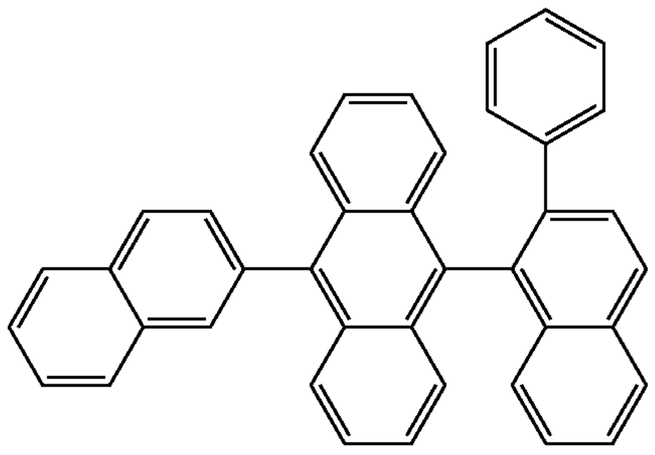
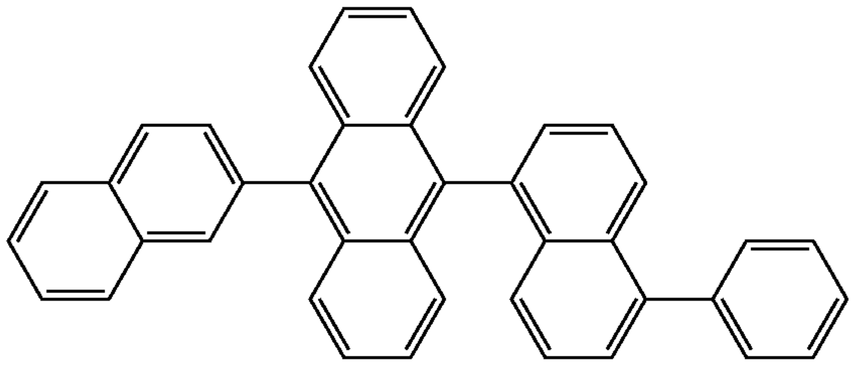
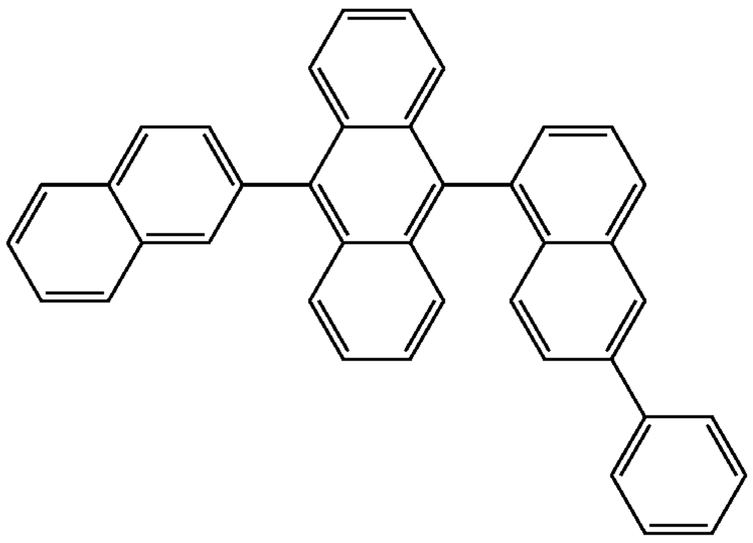
120



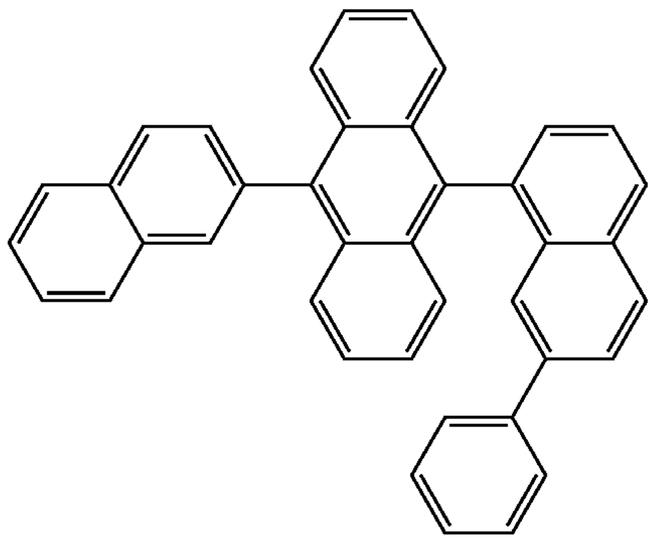
121



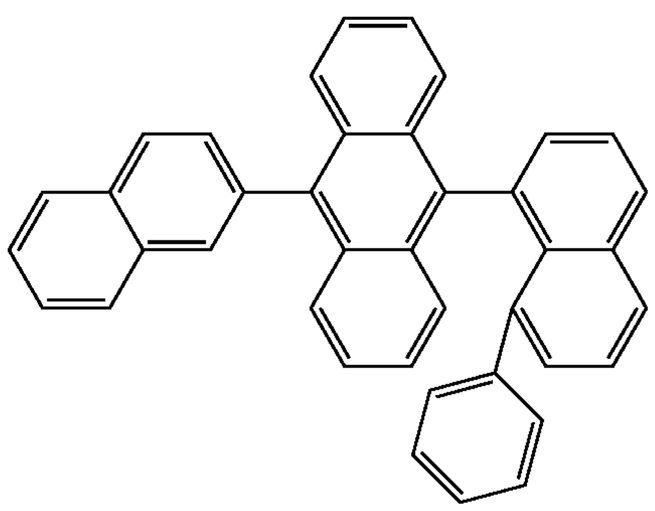
122



123



124



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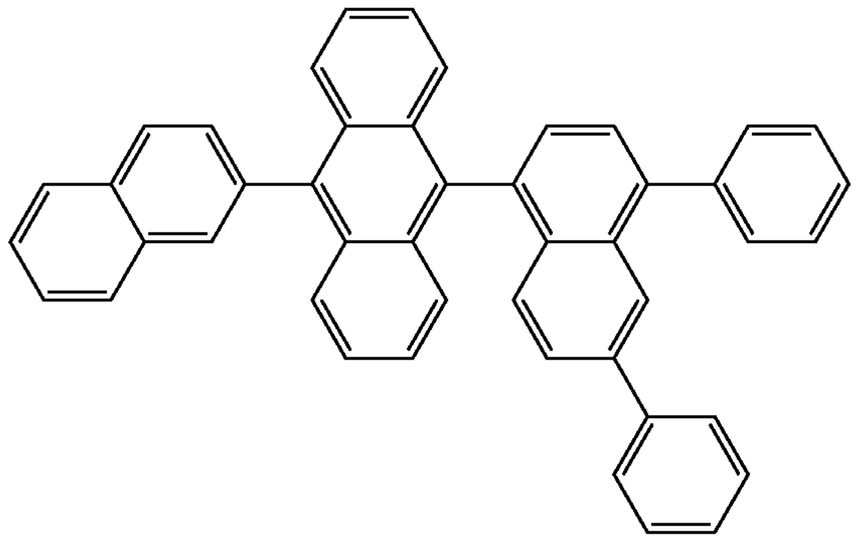
125



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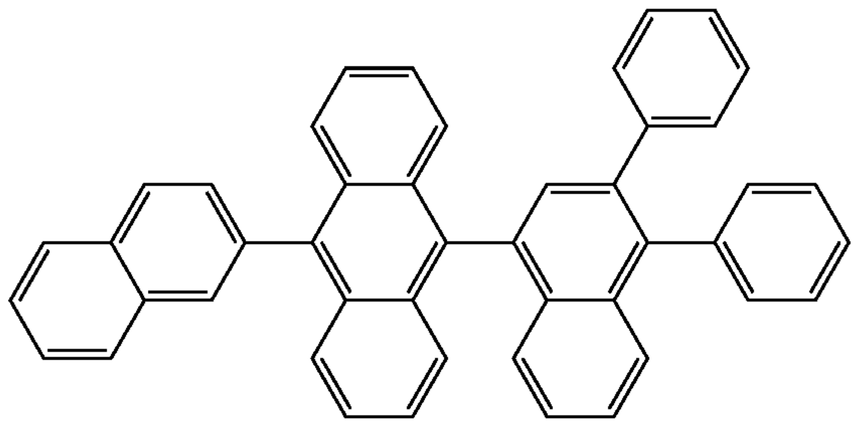

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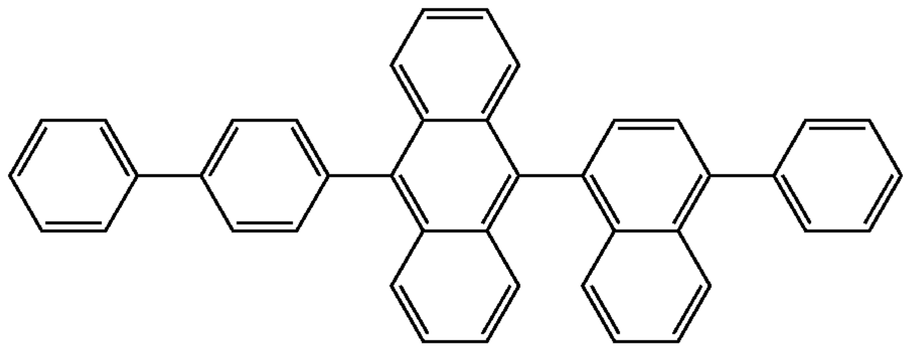

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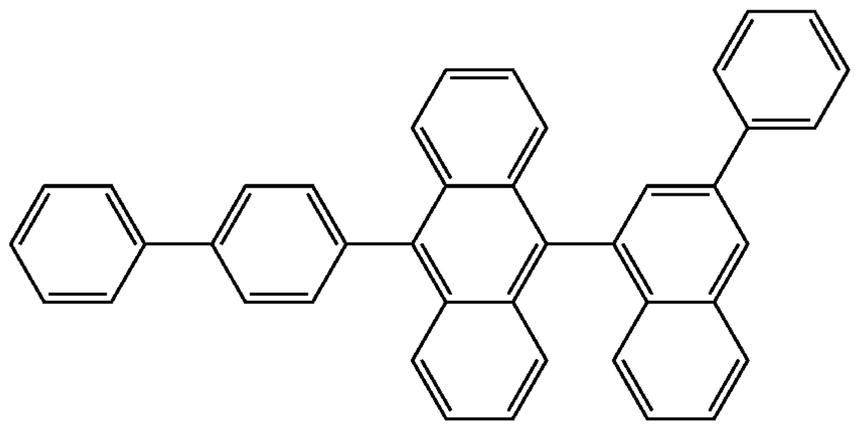

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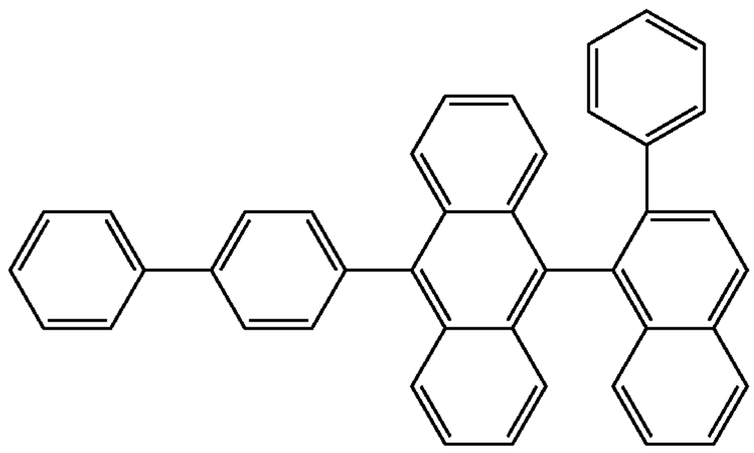

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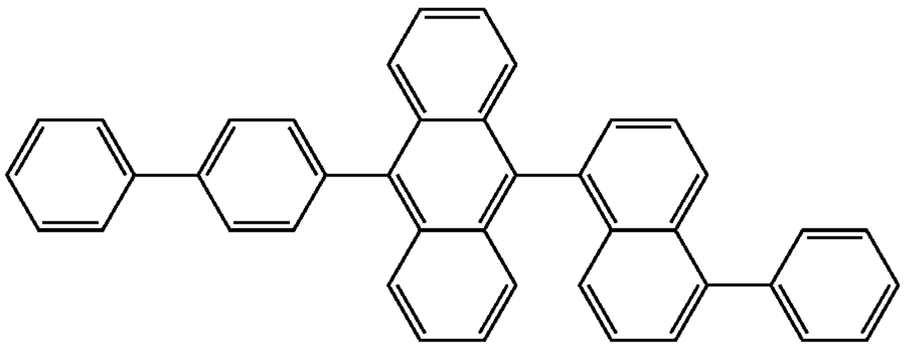

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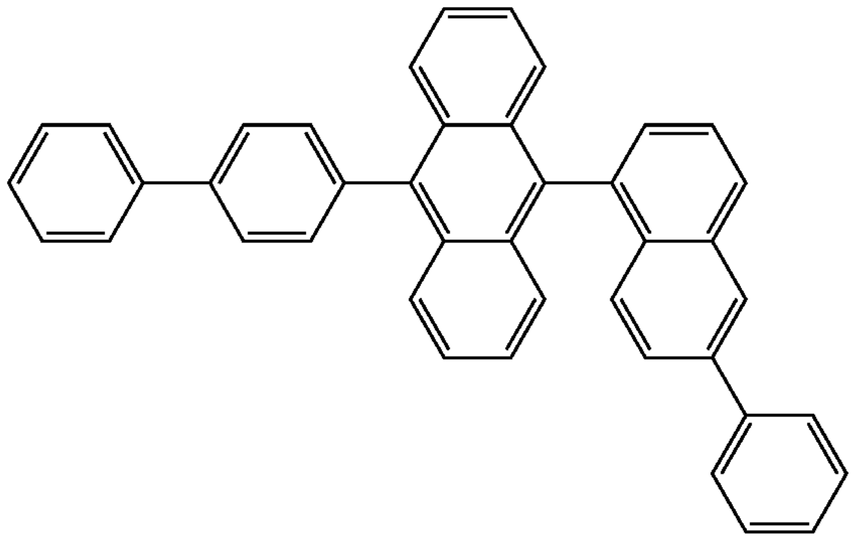

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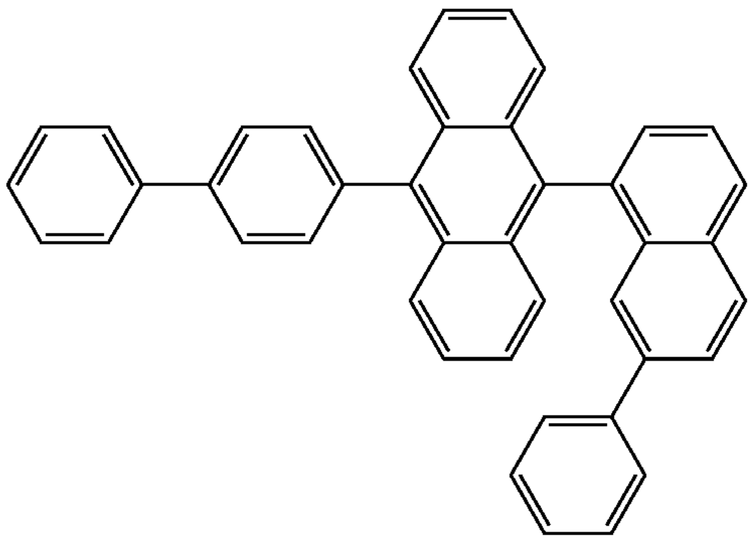

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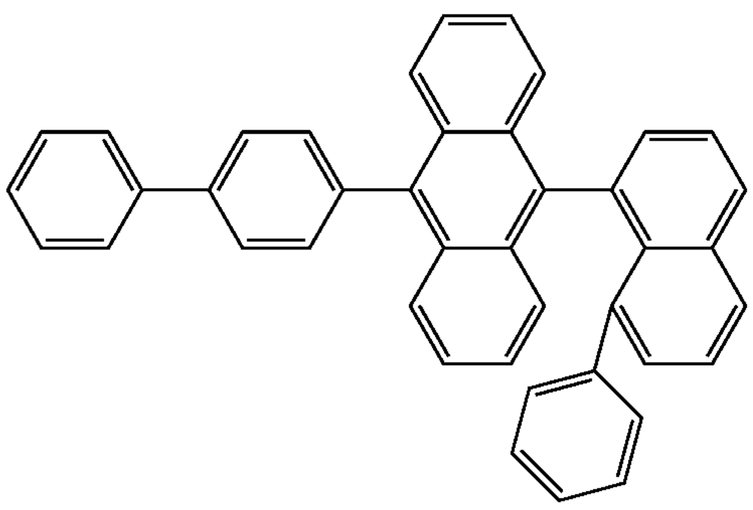

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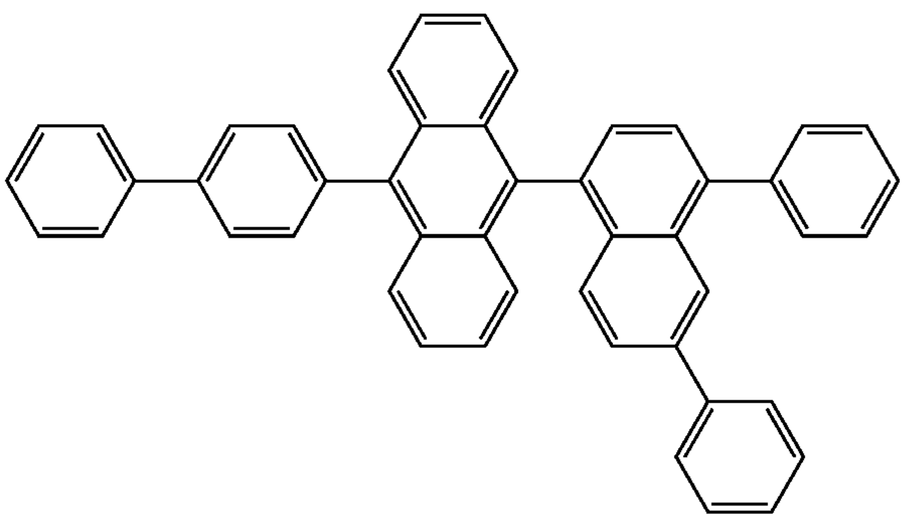

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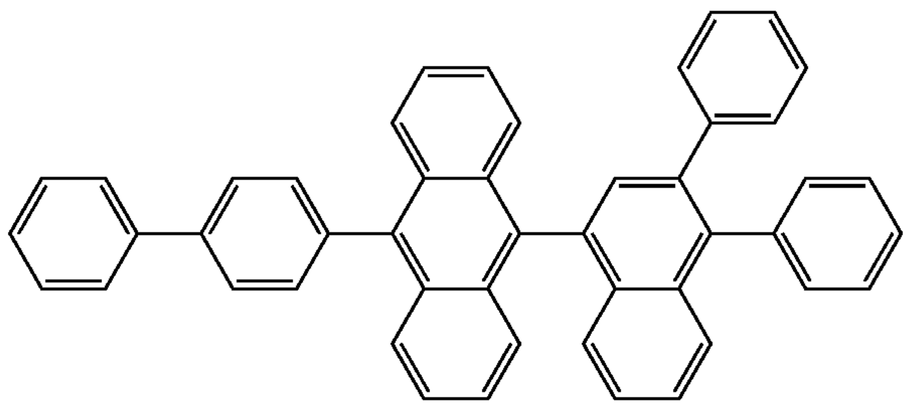

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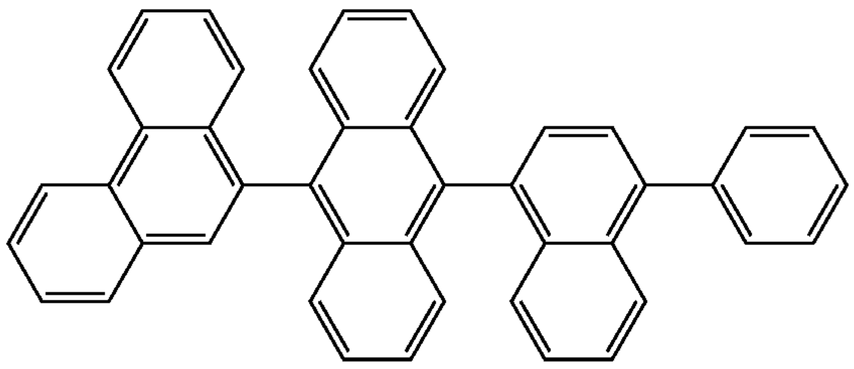

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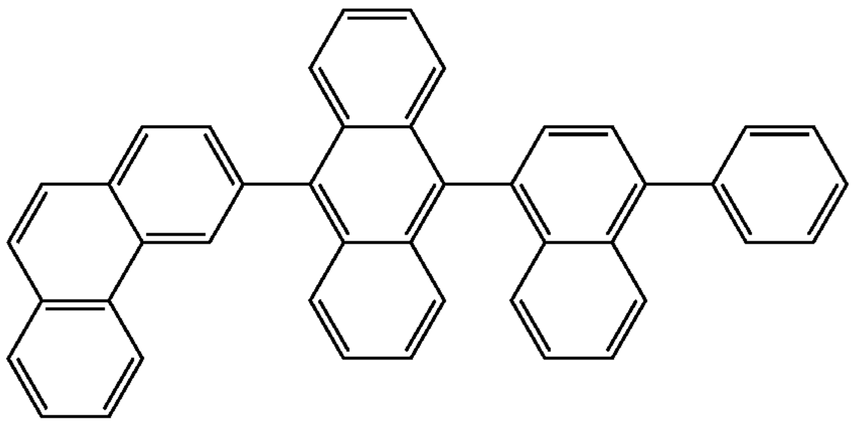

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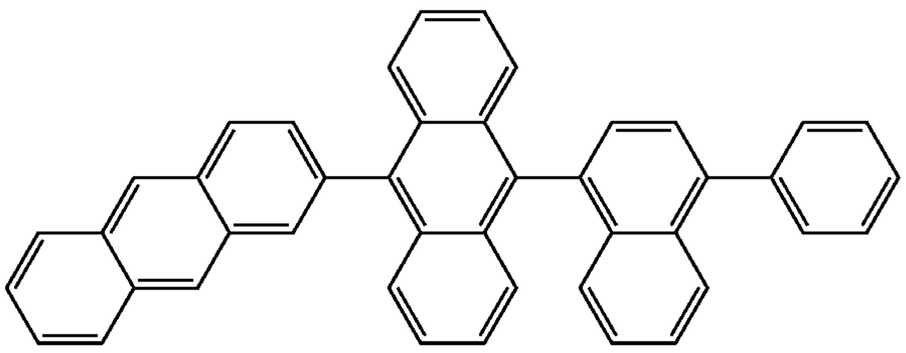

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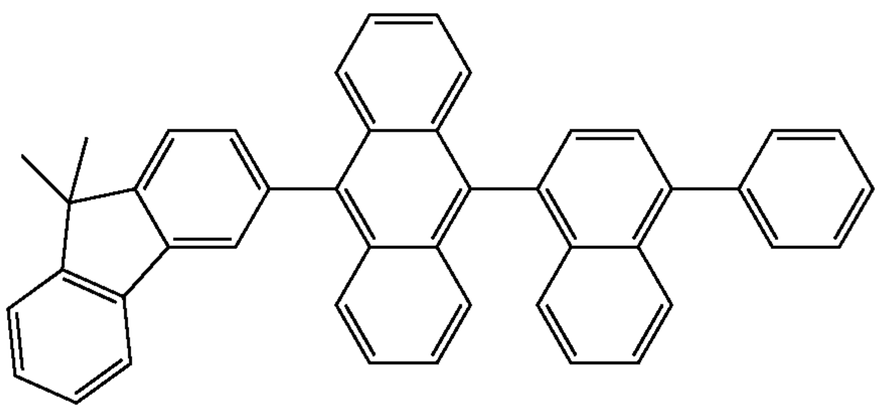

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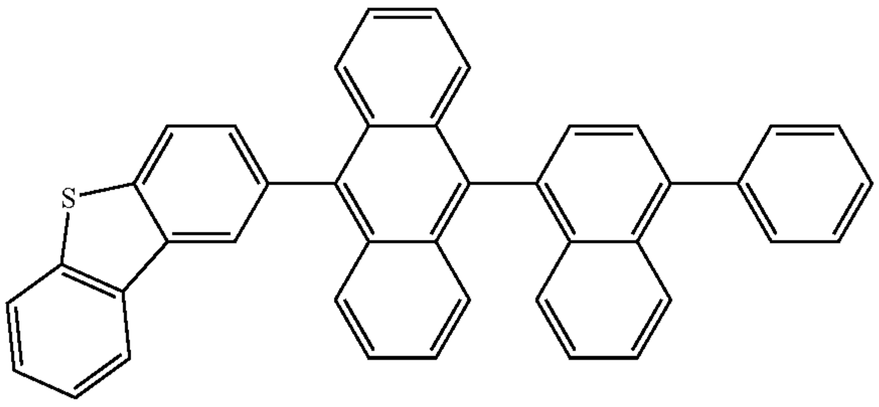

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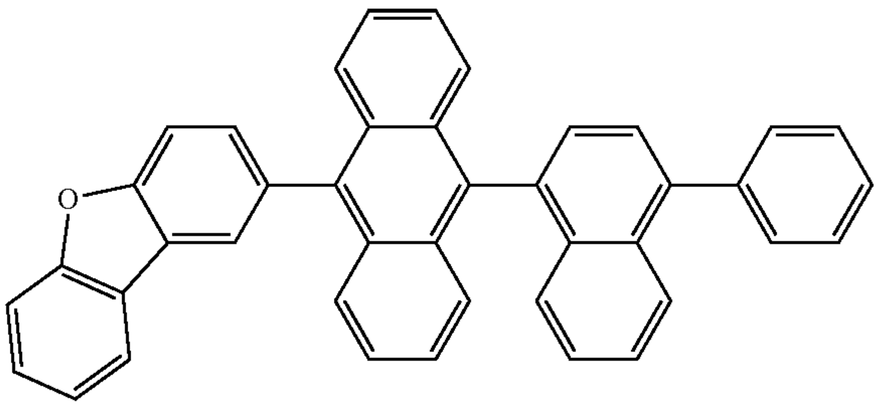

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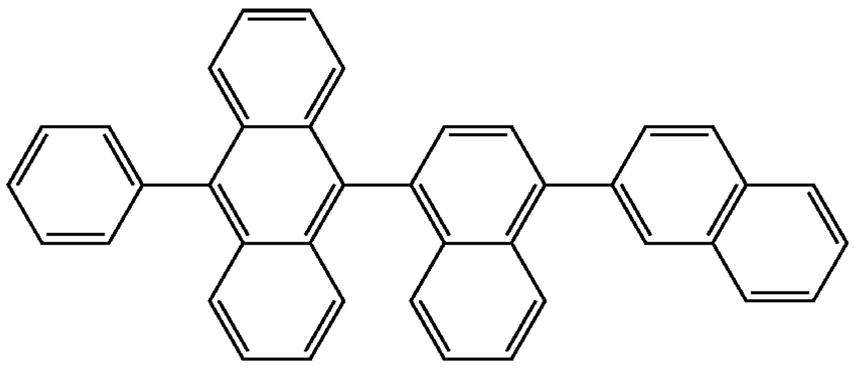

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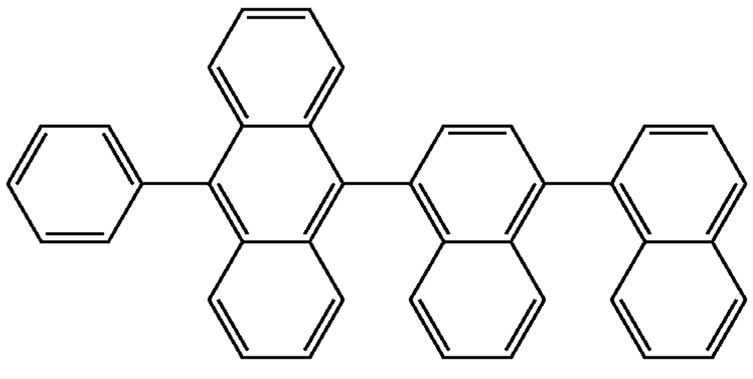

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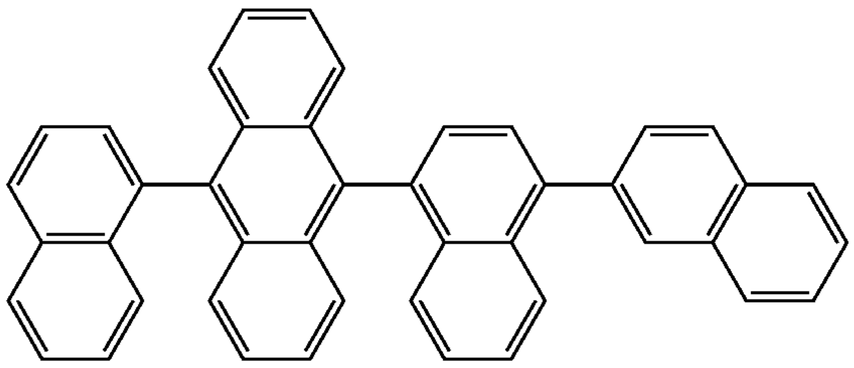

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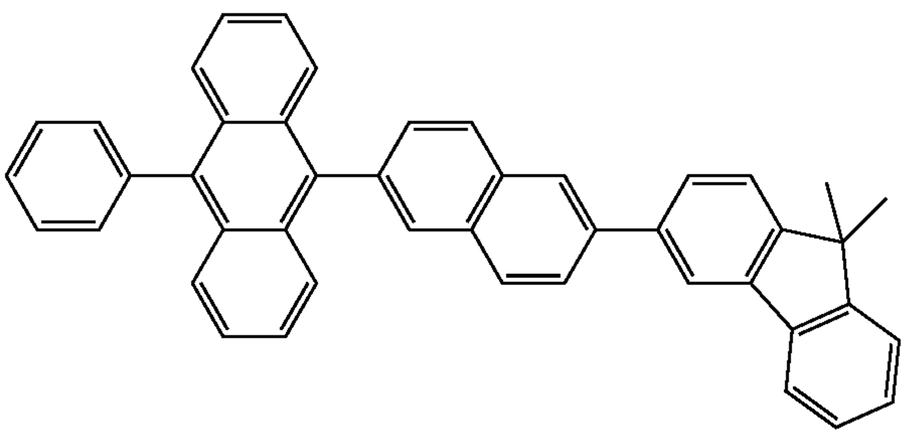

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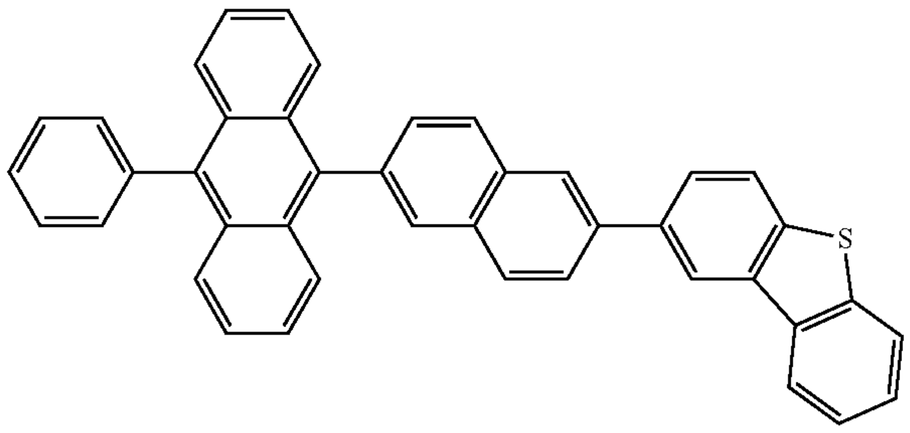

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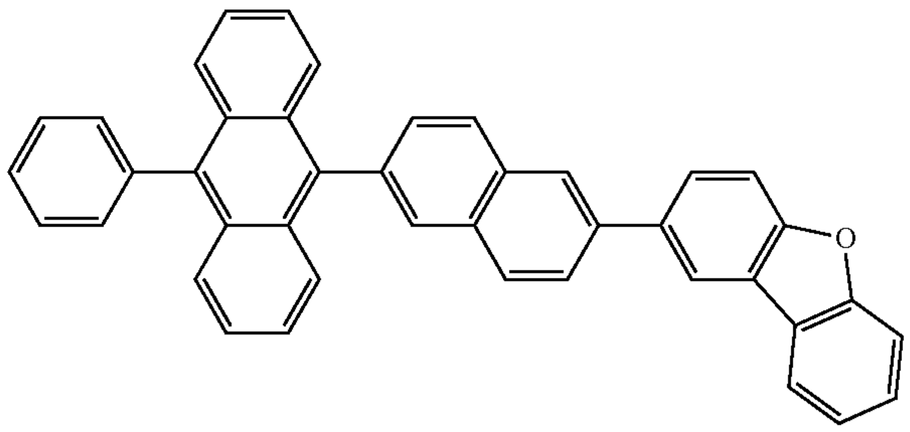

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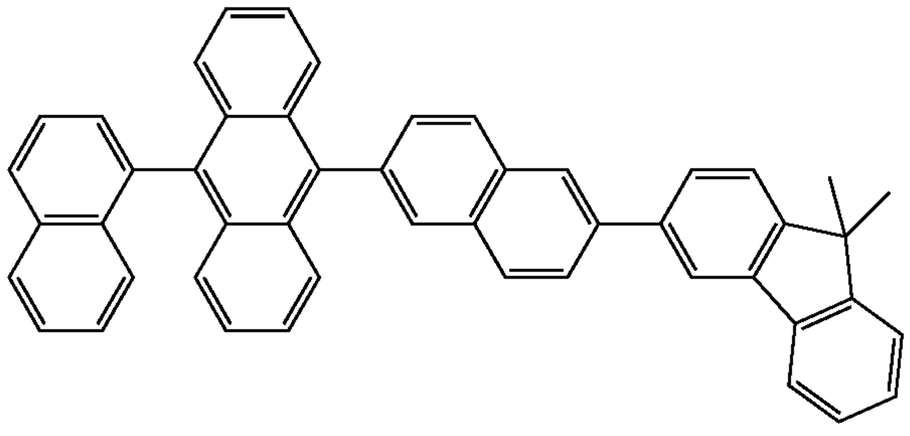

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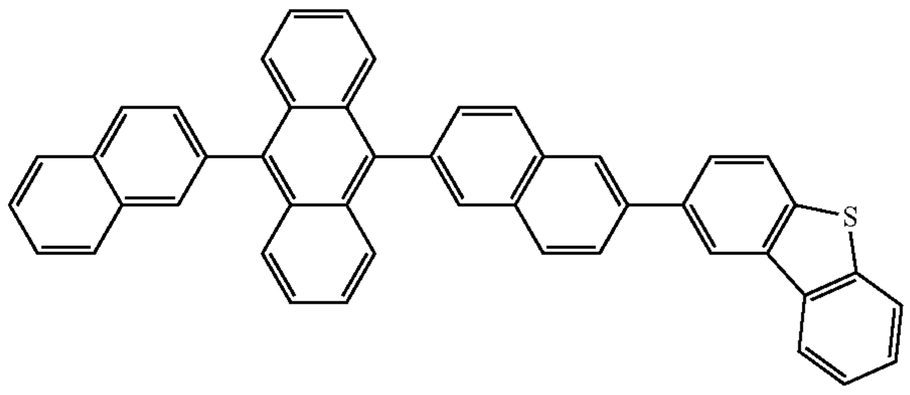

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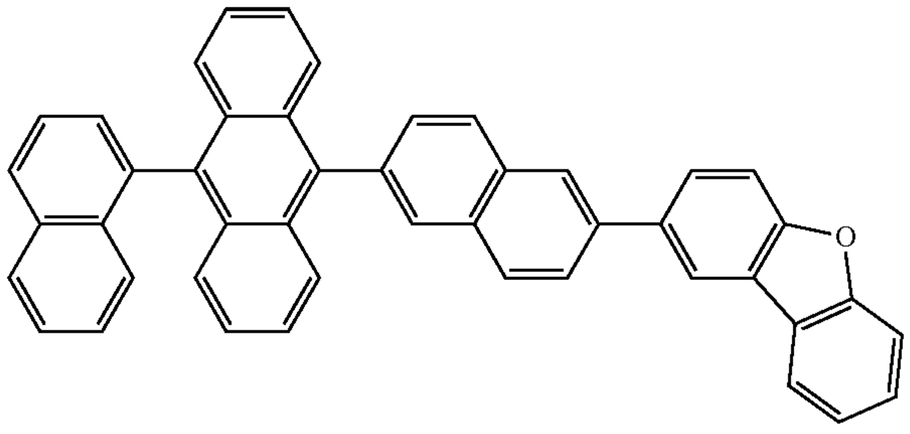

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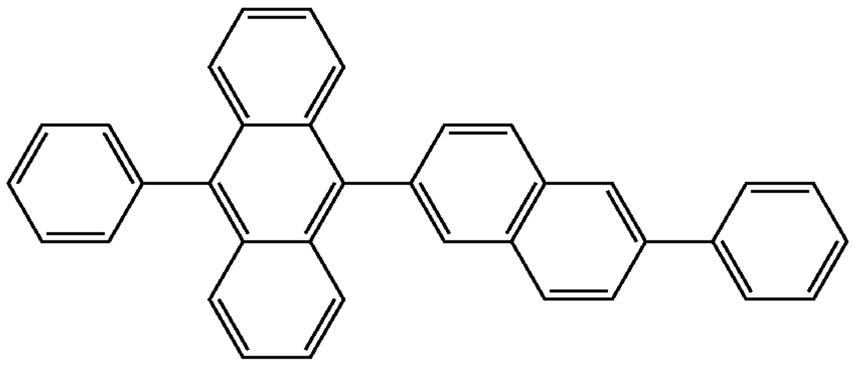

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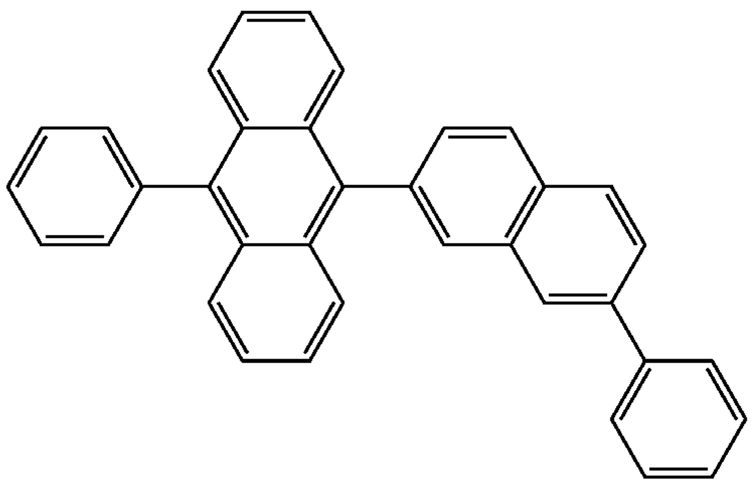

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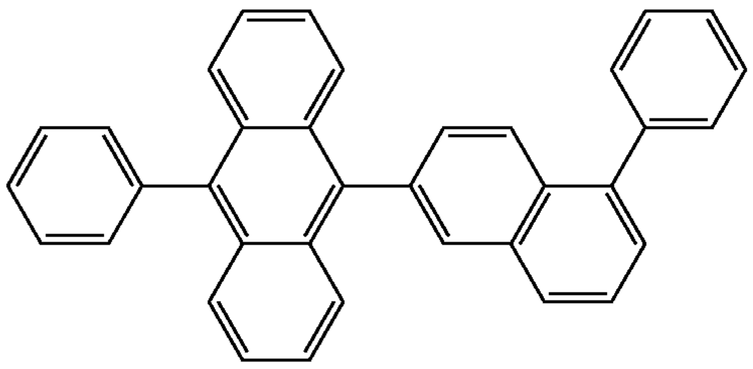

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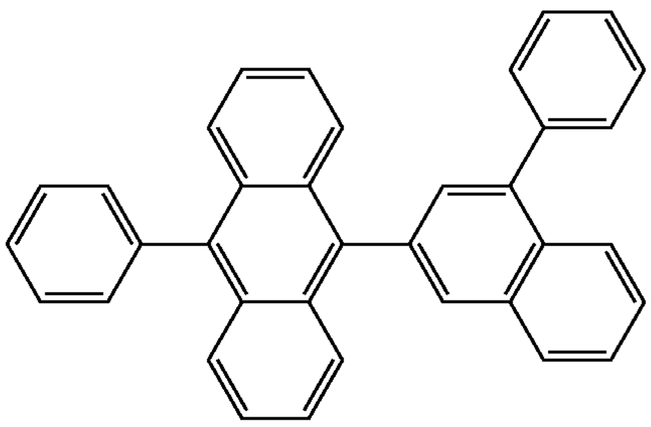

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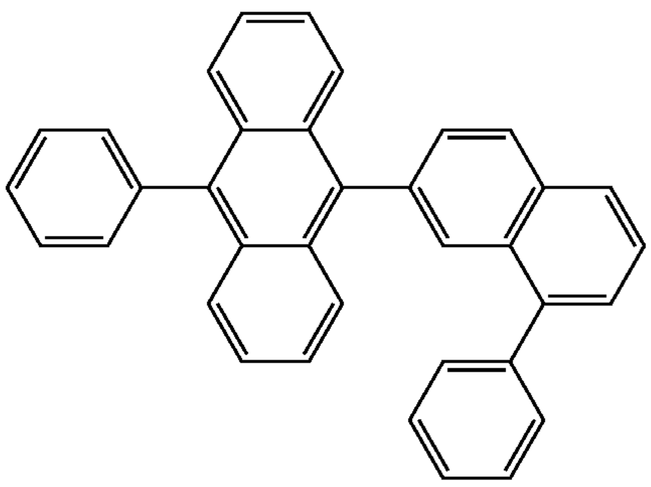

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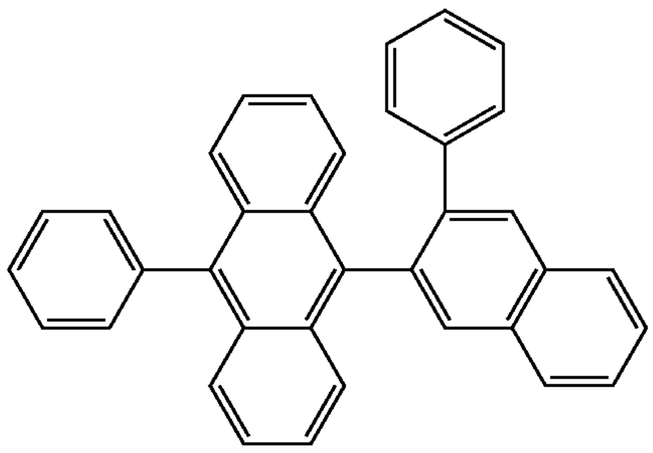

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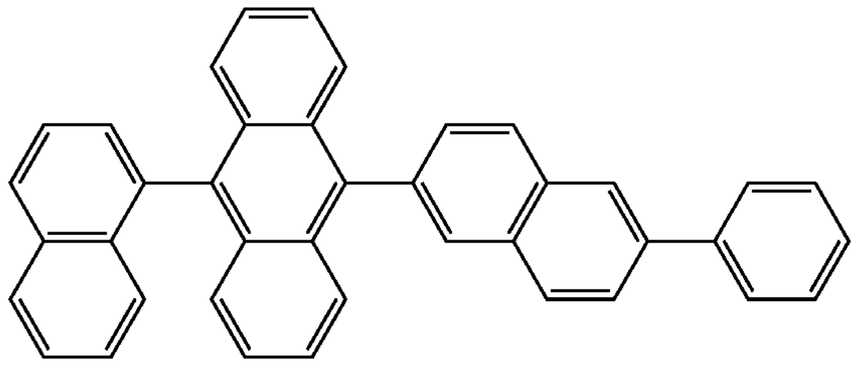

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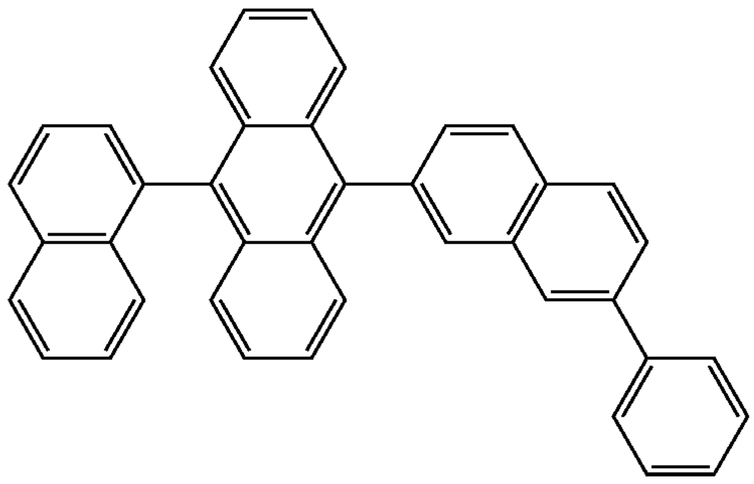

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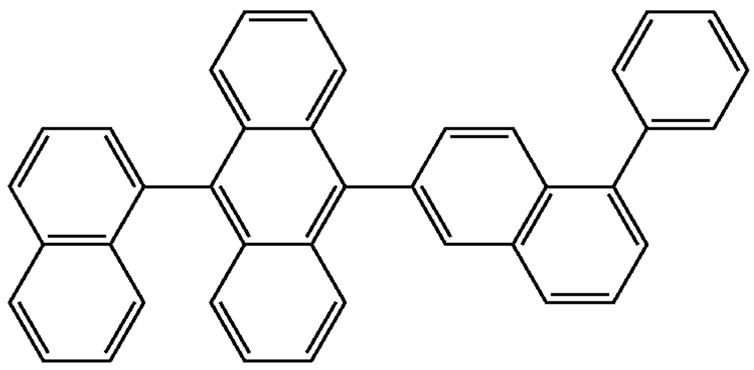

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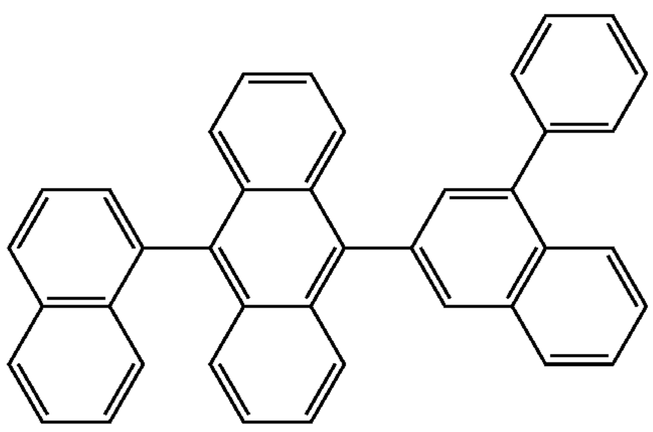

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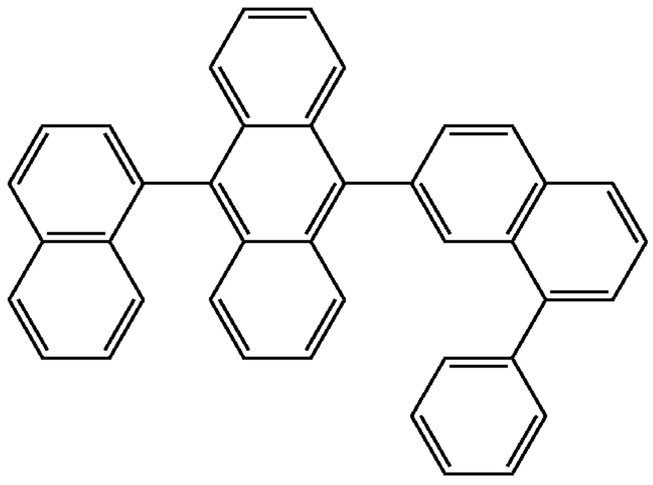

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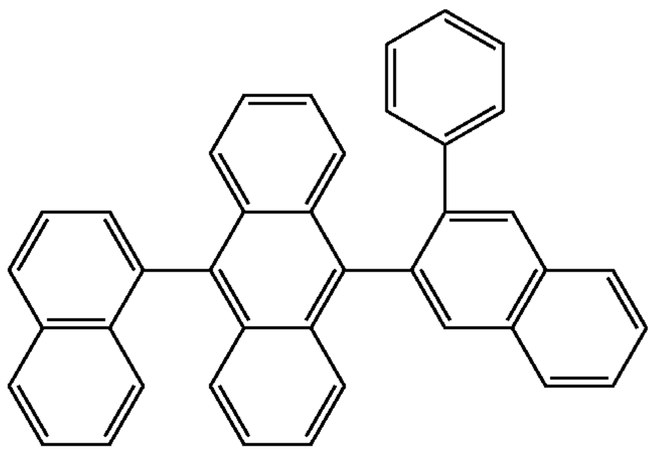

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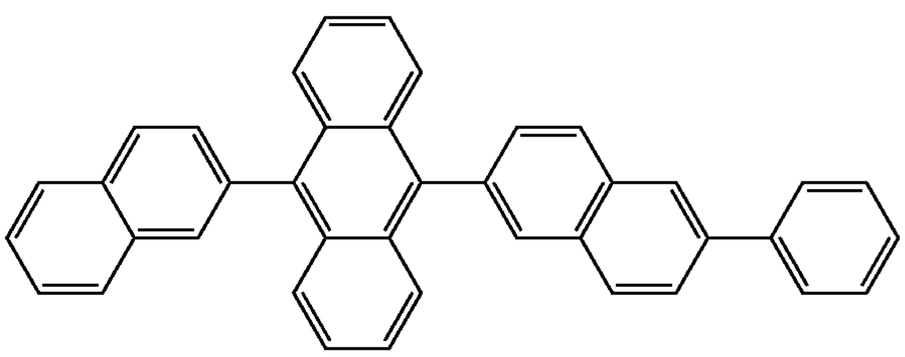

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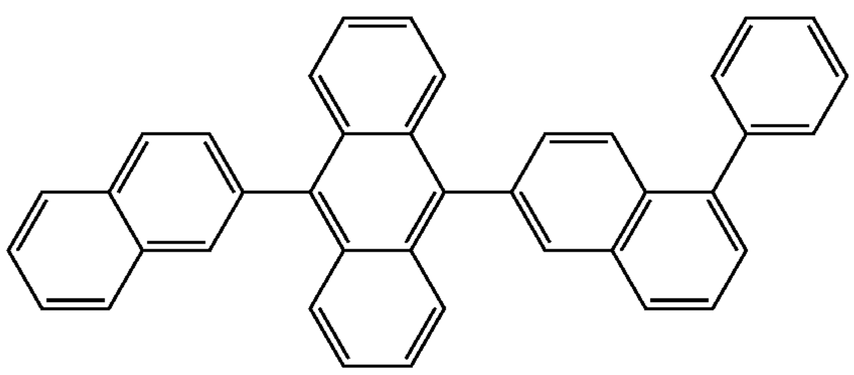

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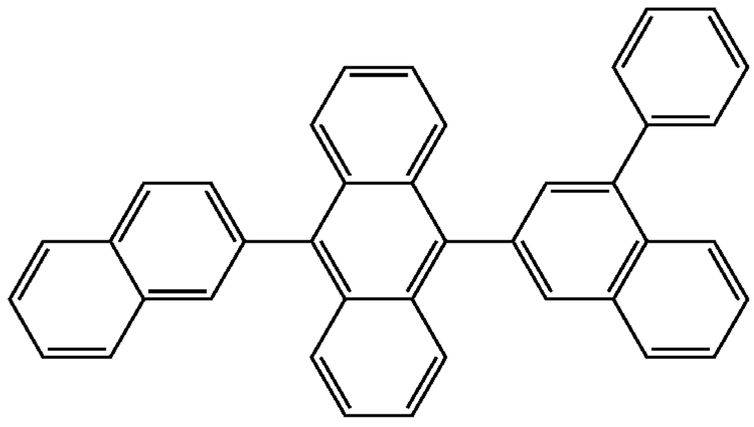

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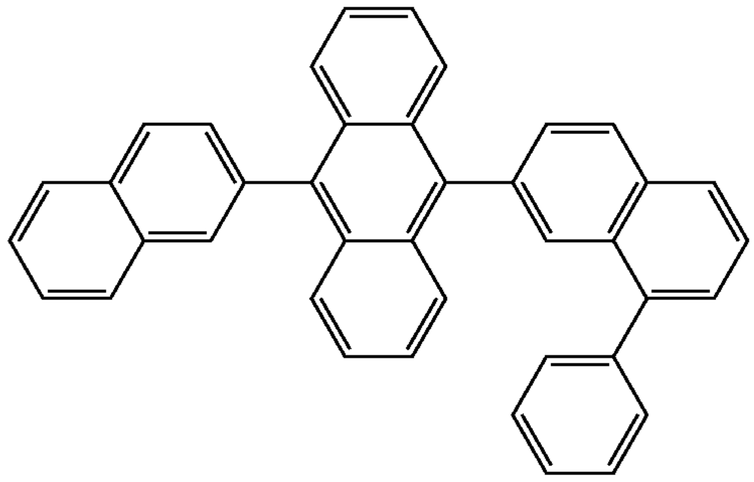

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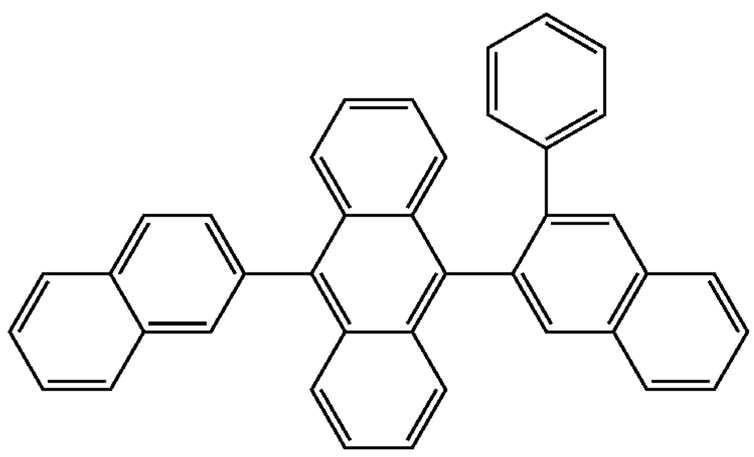

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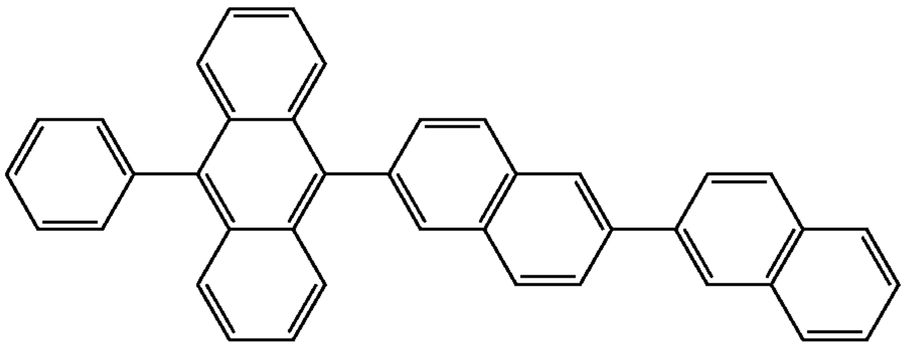

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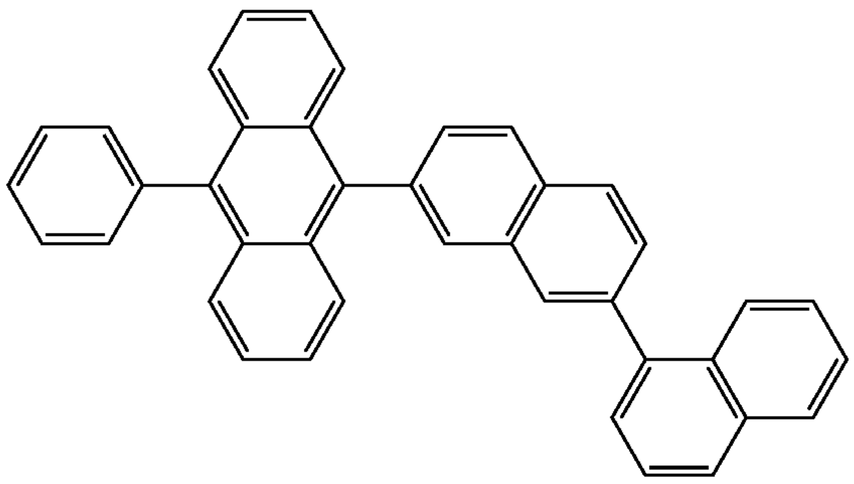

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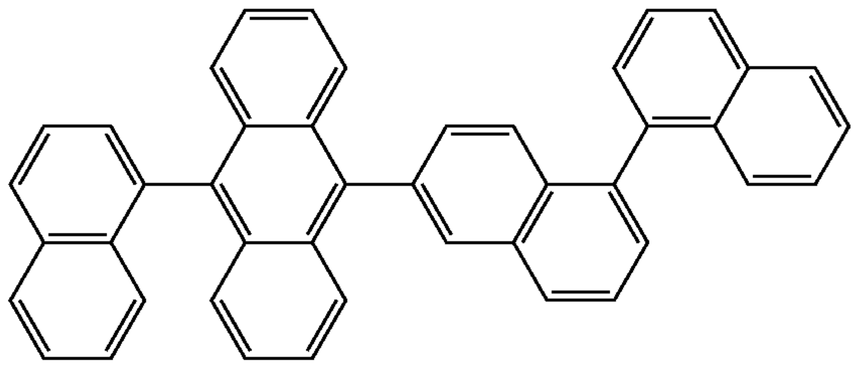

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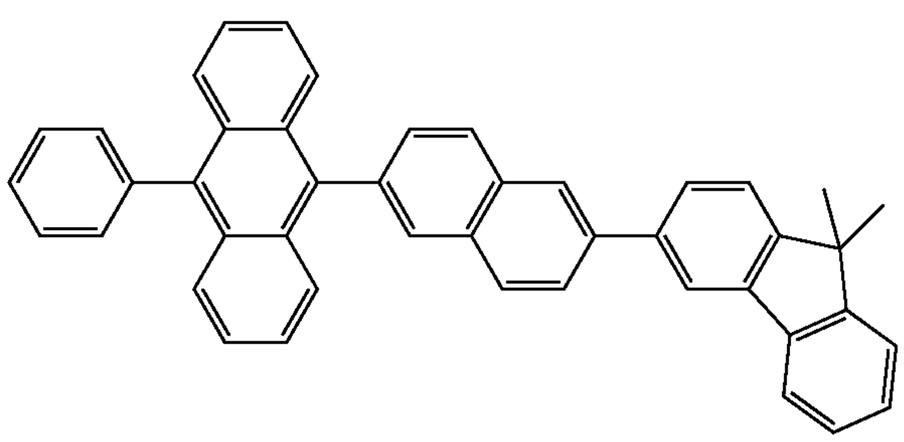

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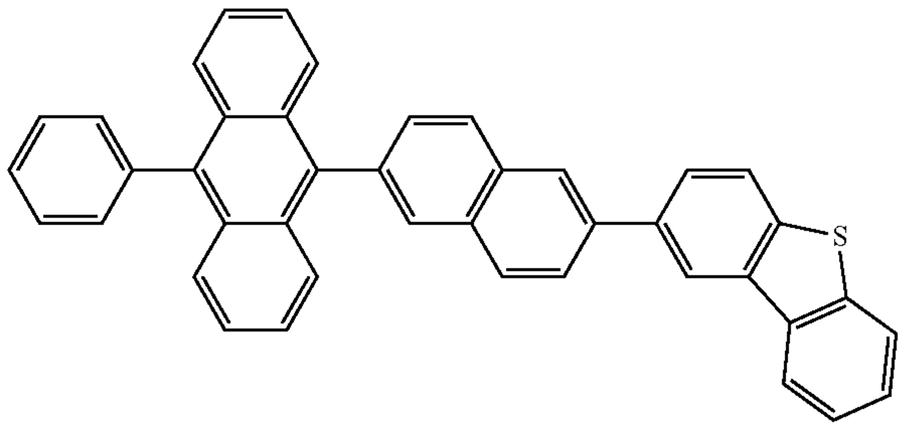

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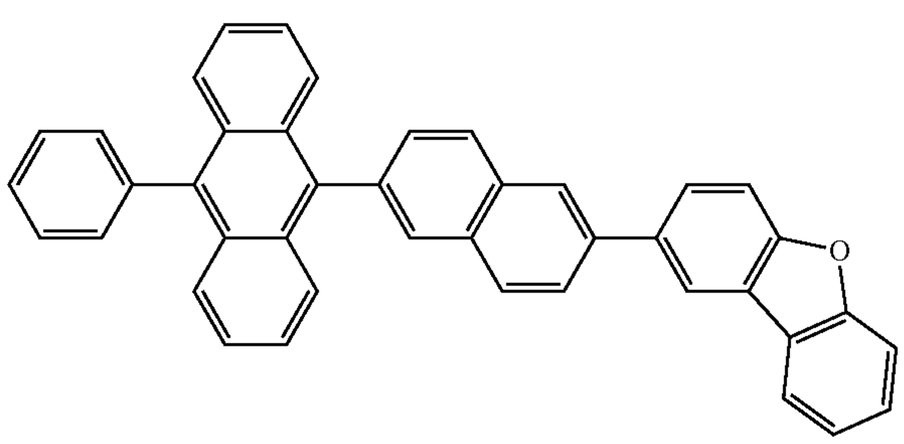

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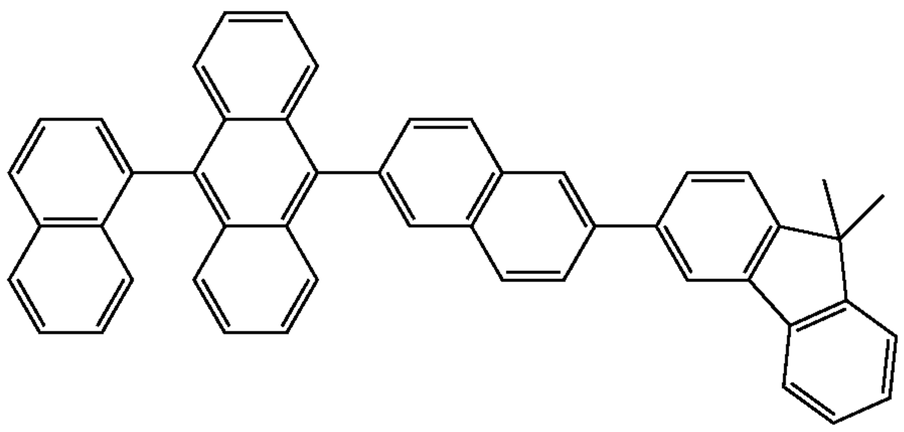

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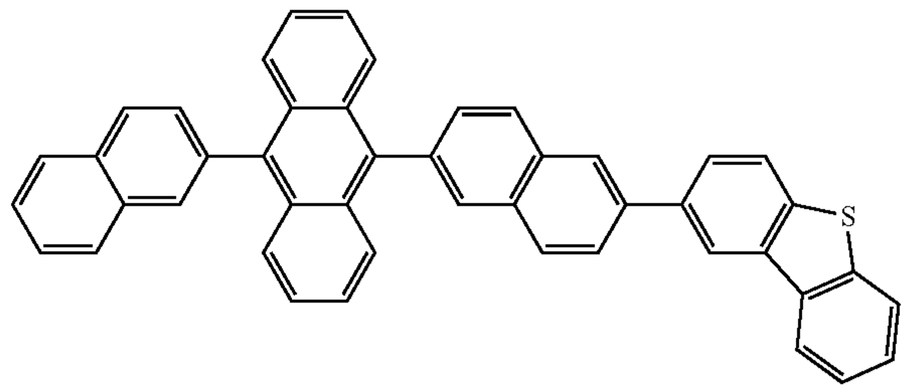

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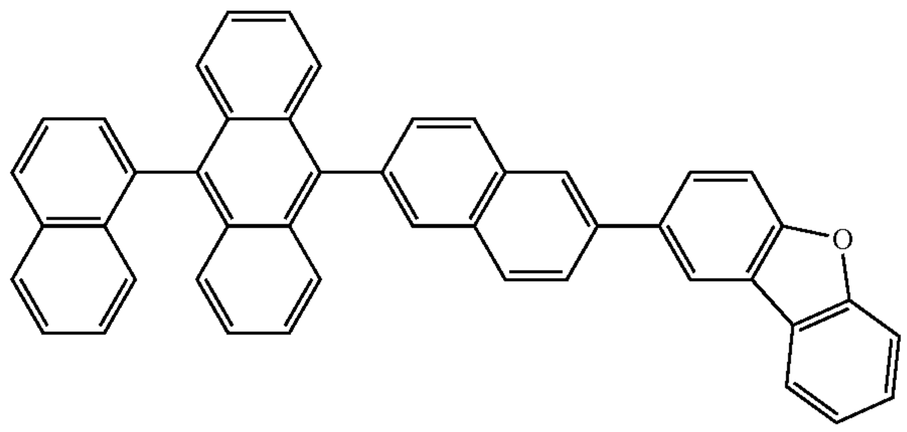

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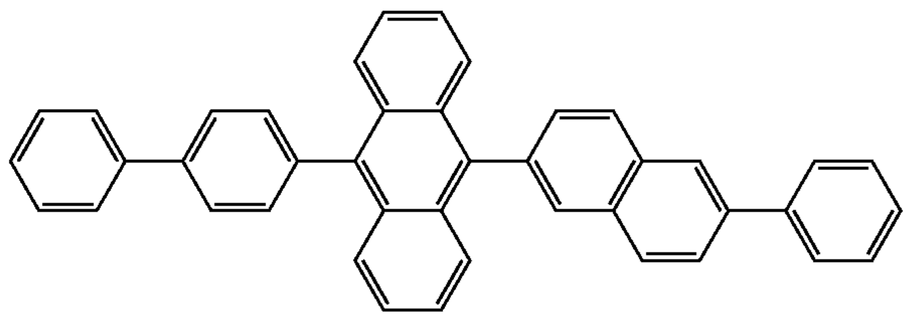

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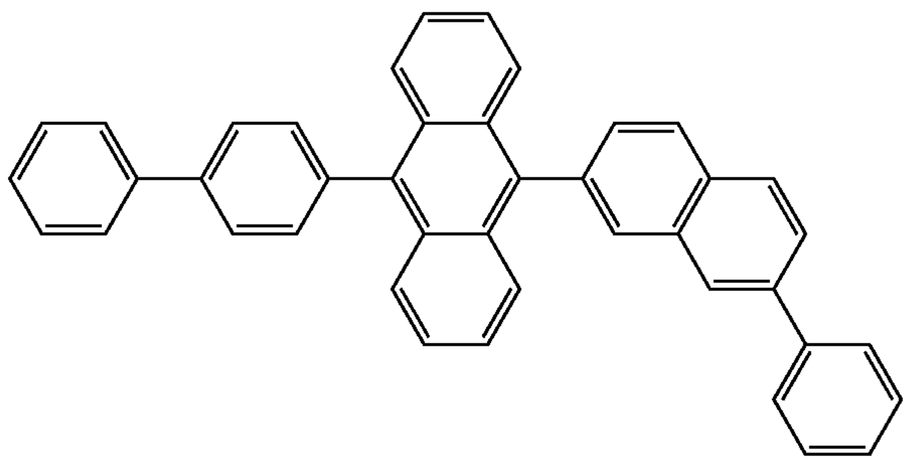

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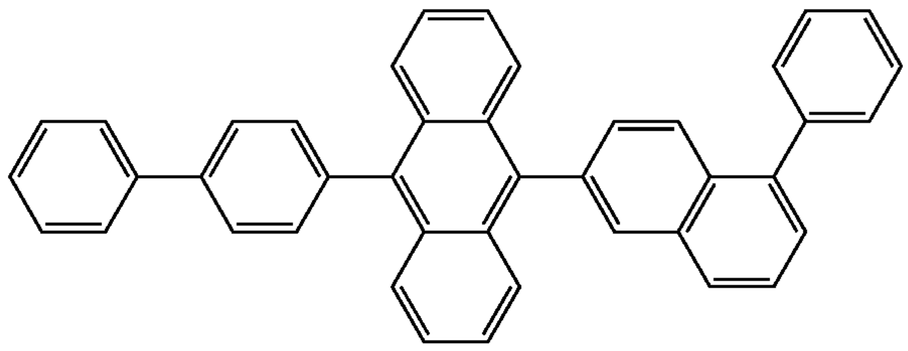

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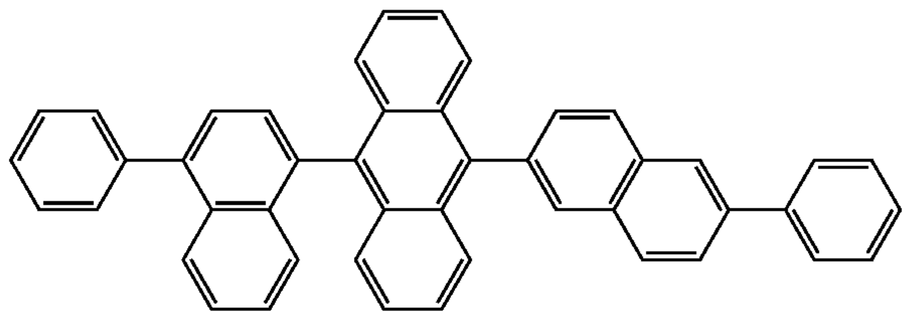

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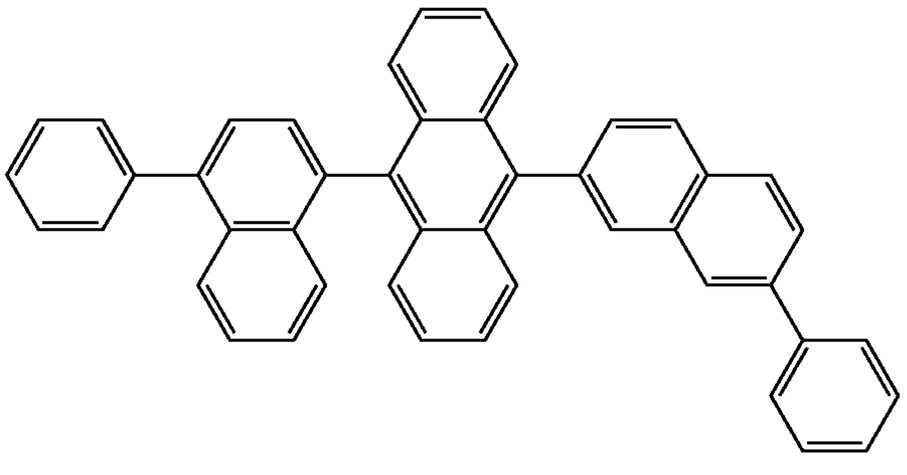

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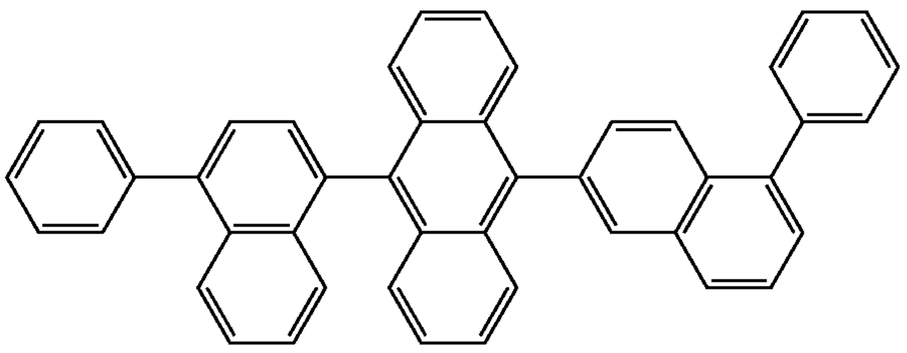

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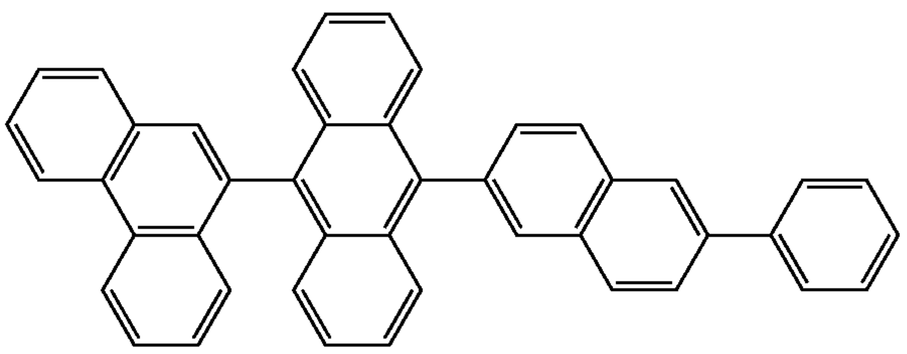

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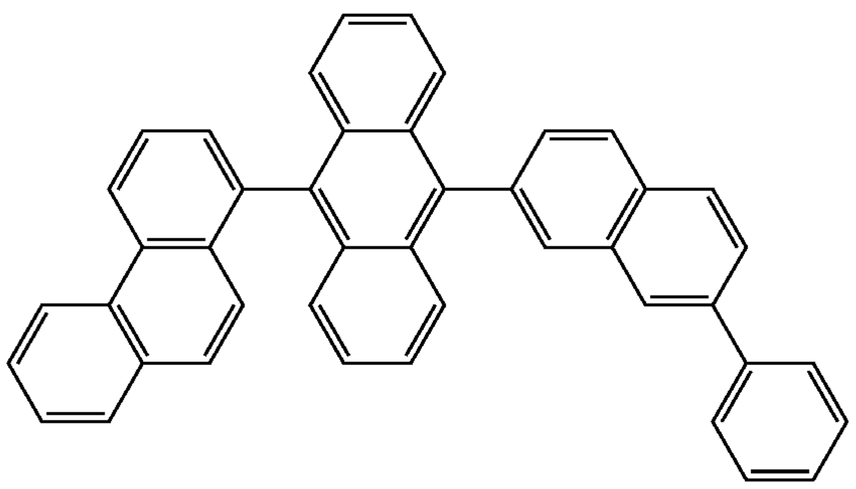

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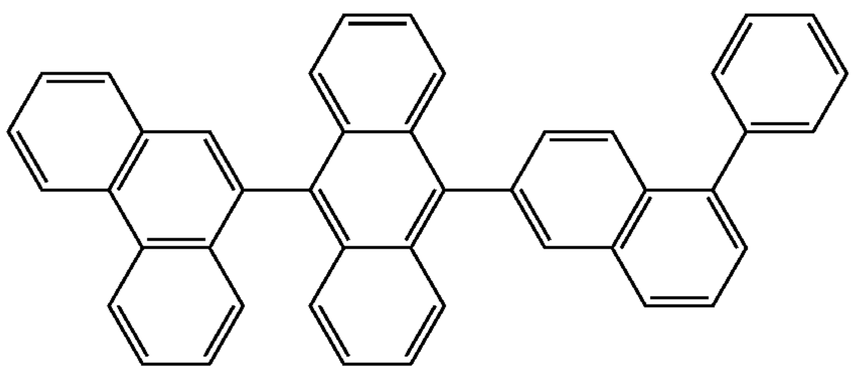

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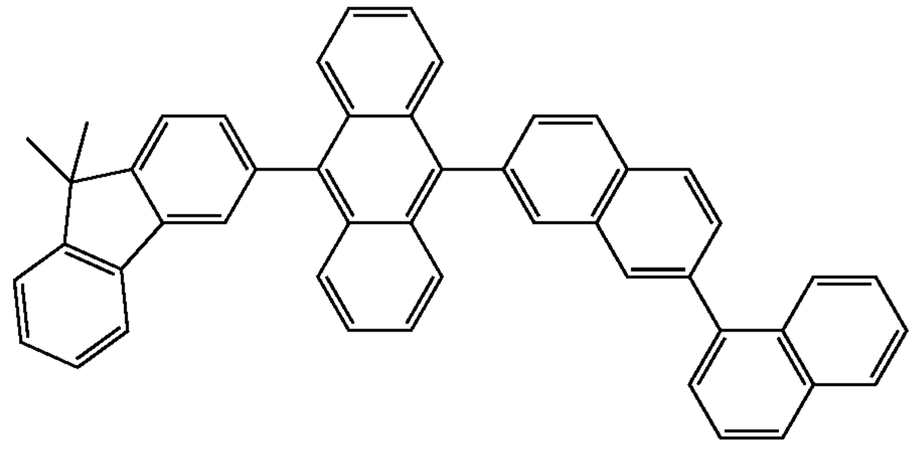

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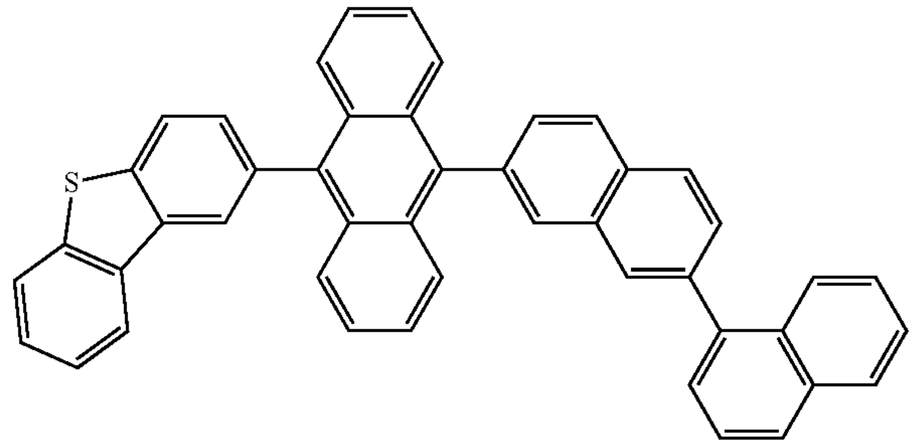

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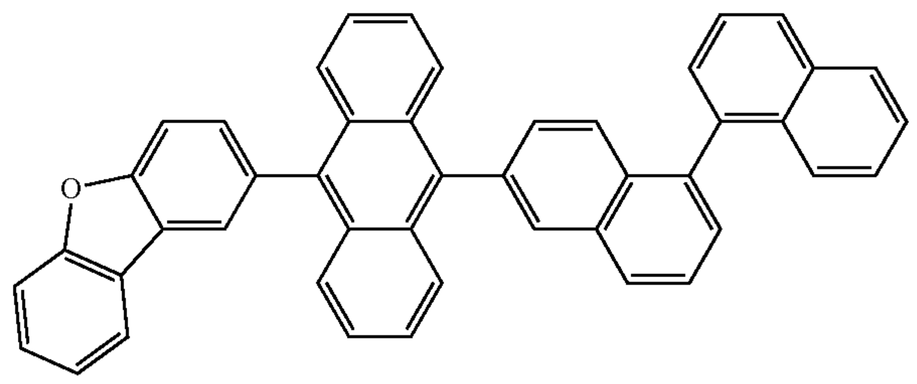

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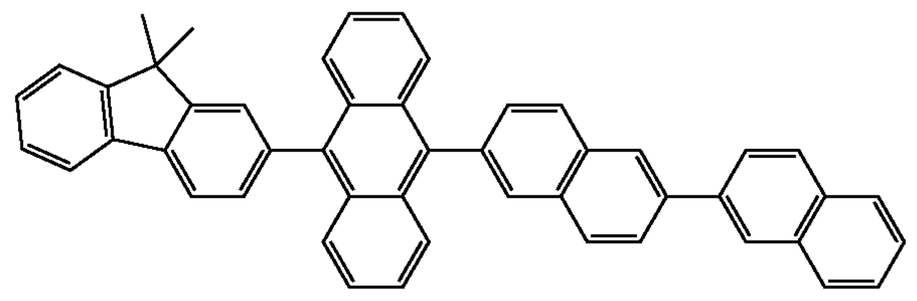

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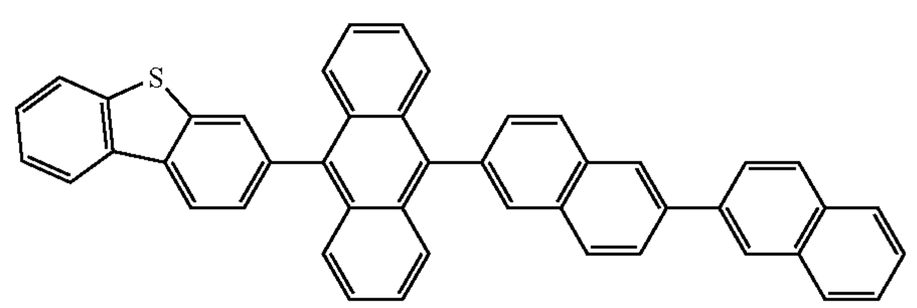

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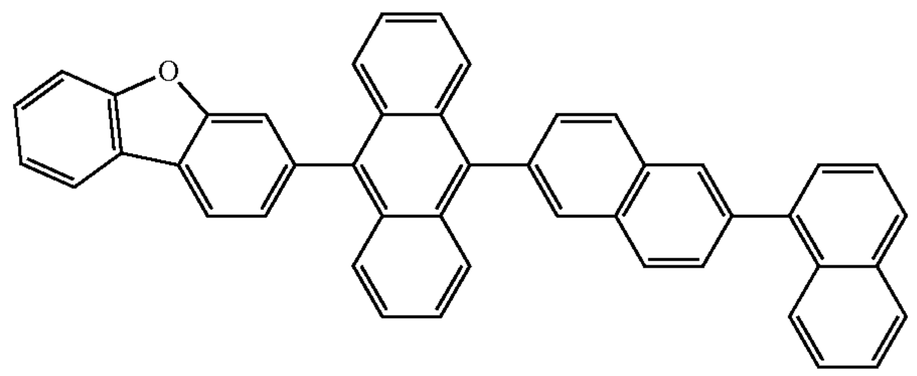

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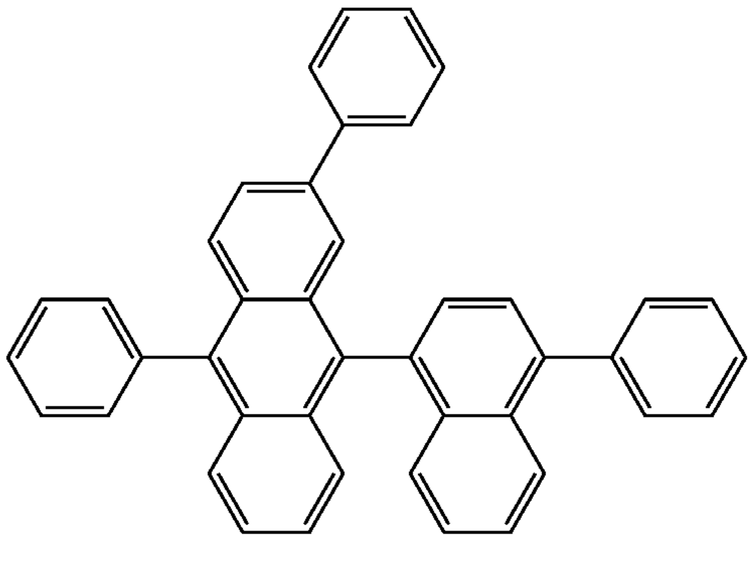

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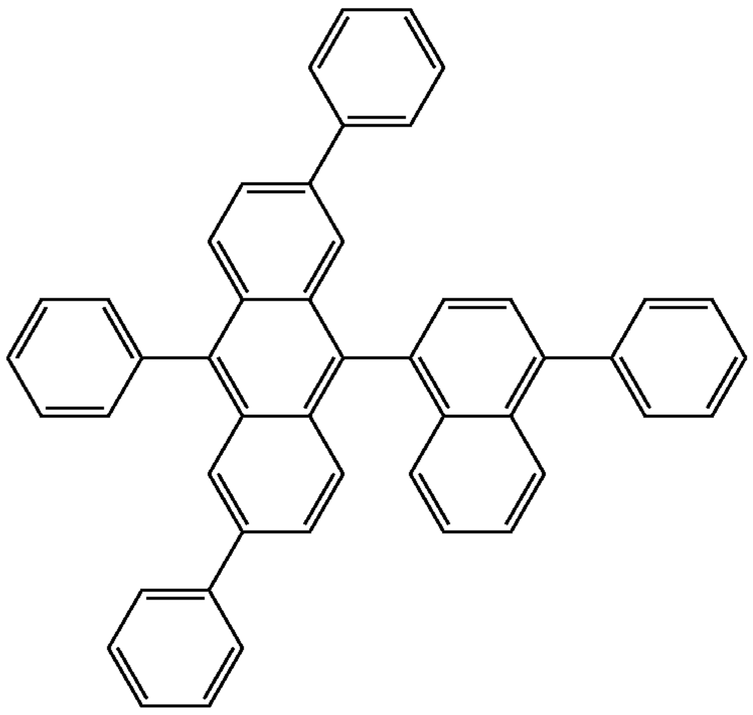

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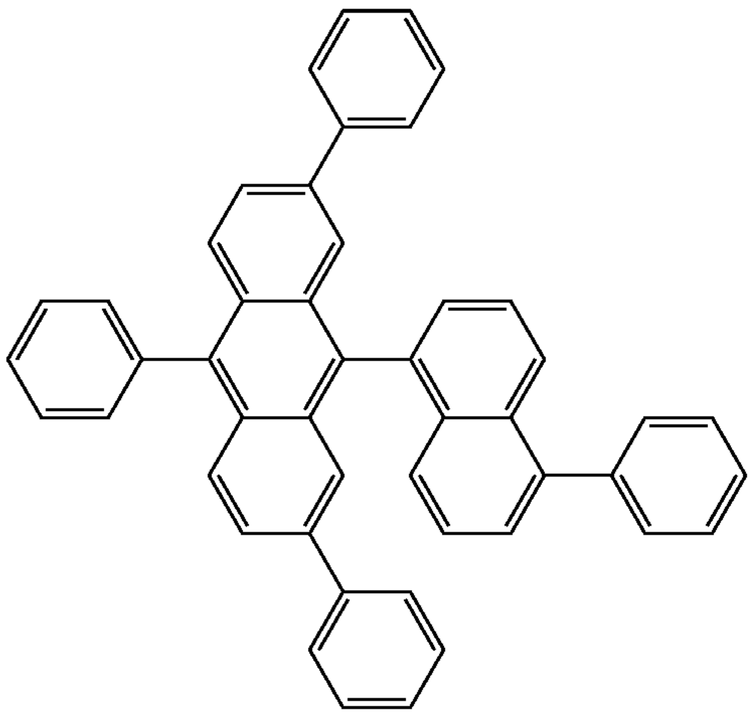

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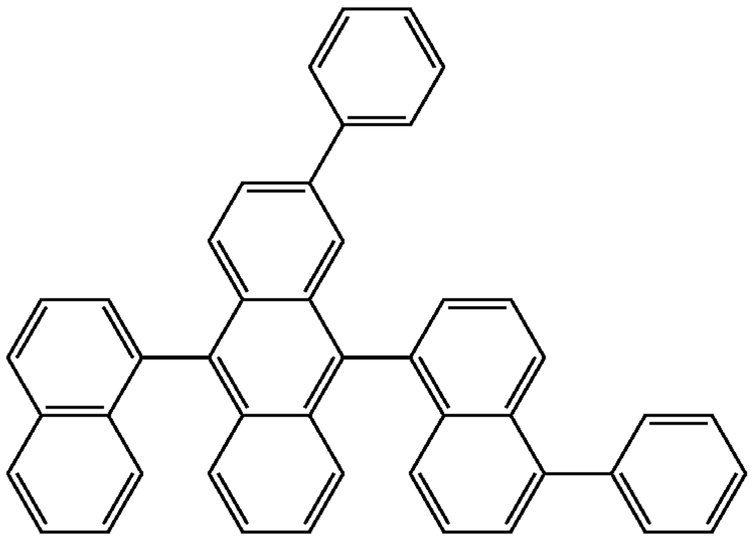

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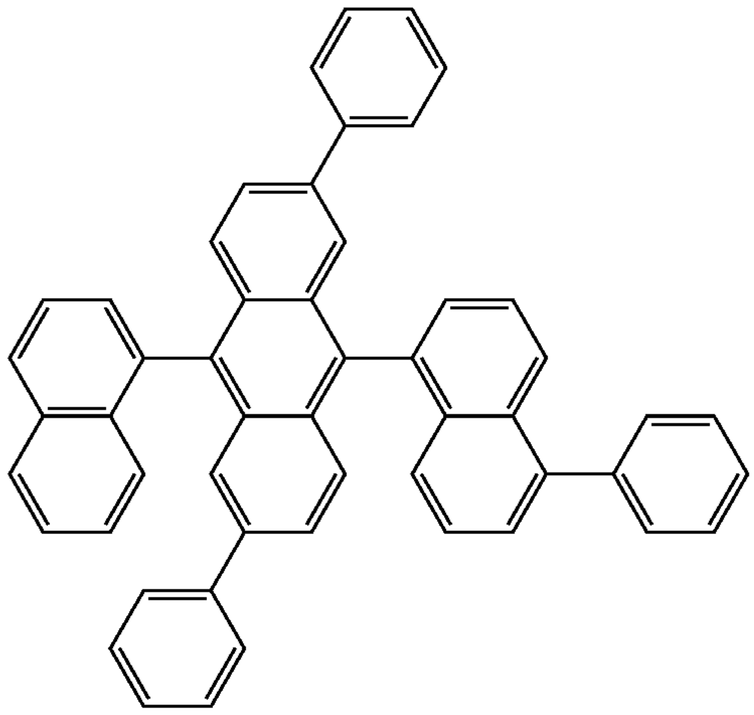

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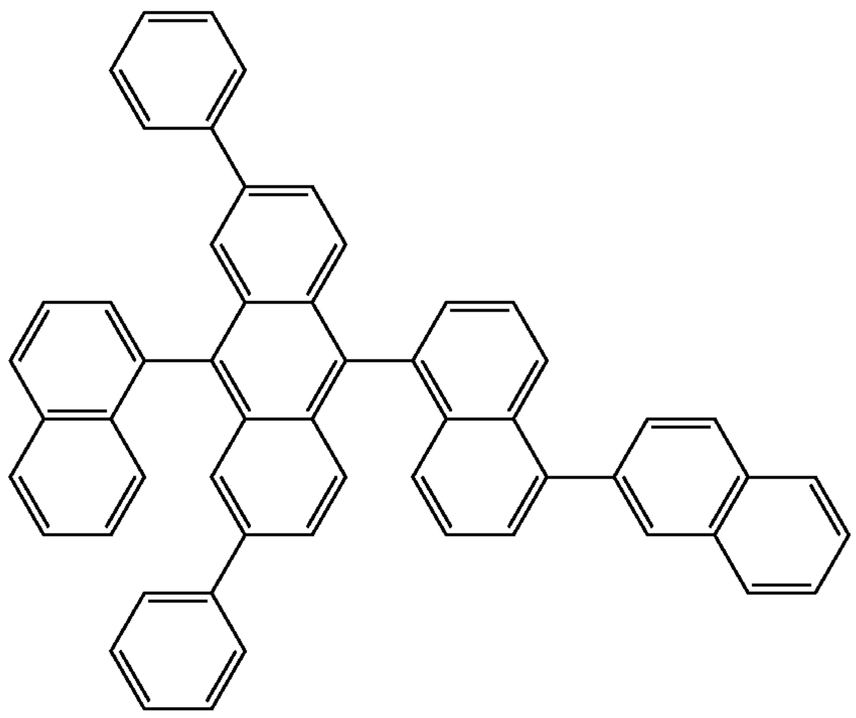

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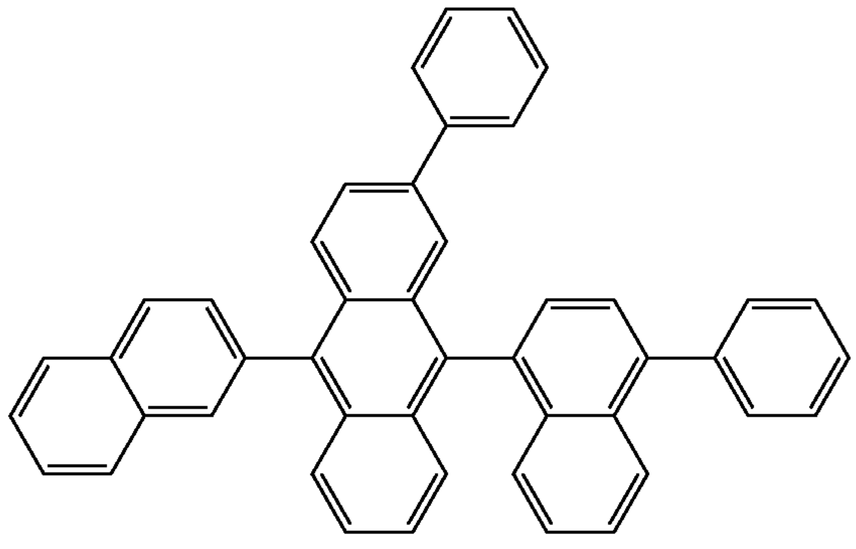

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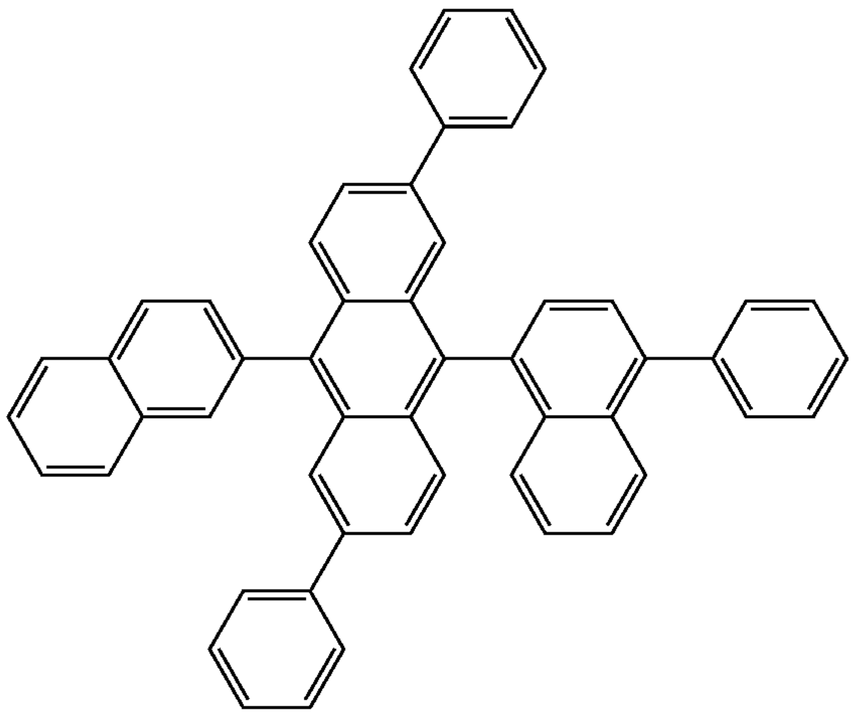

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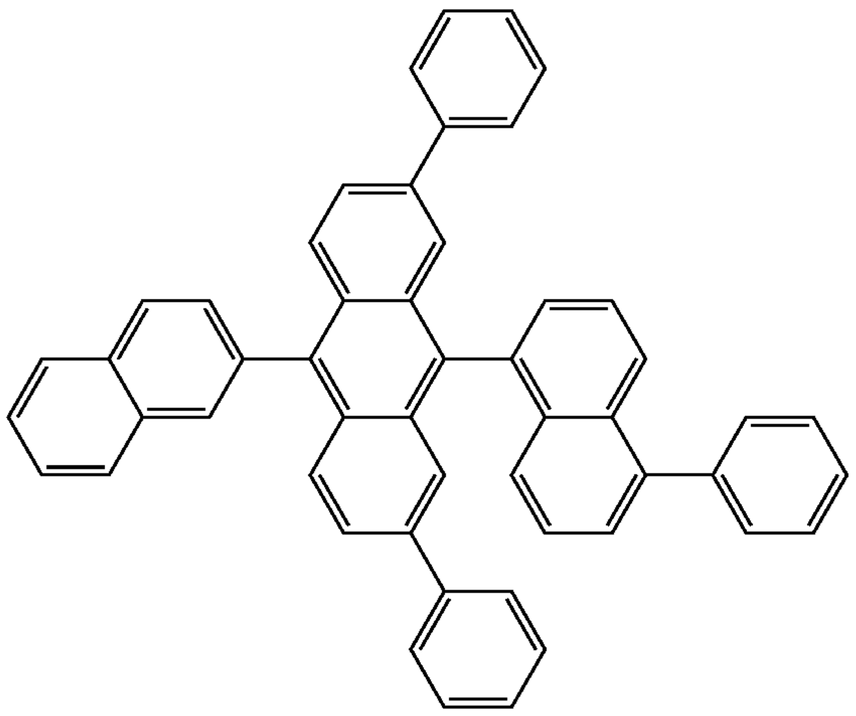

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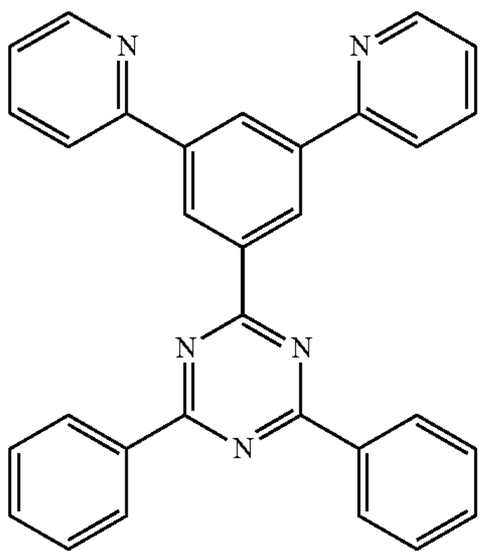

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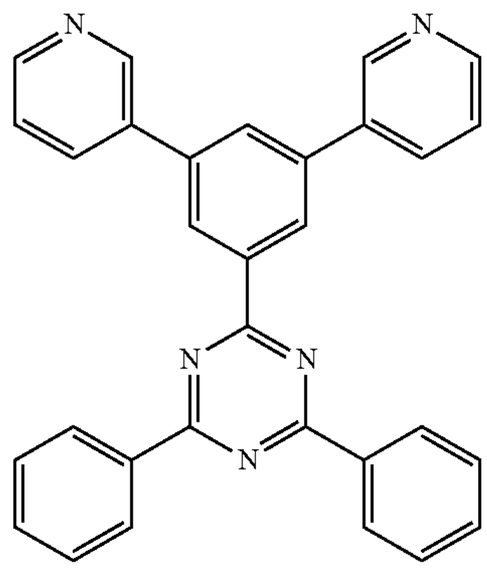

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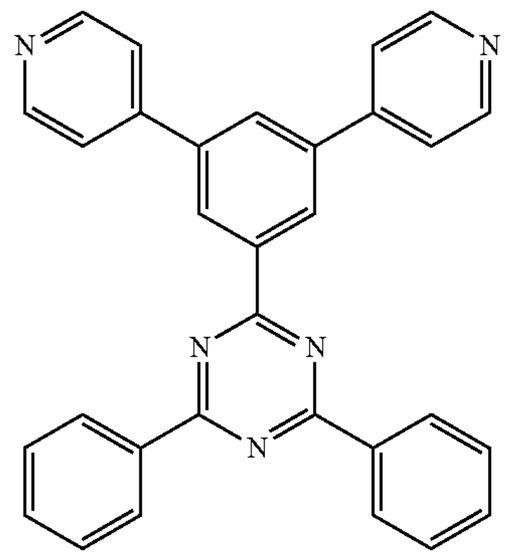

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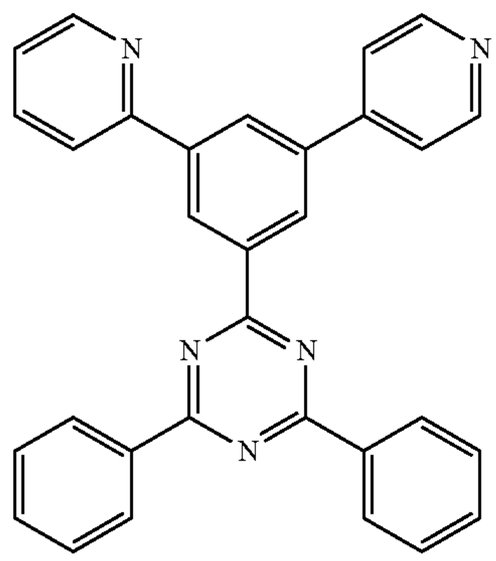

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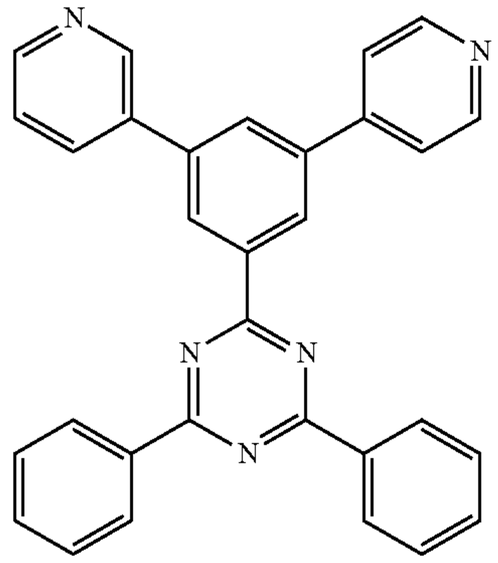

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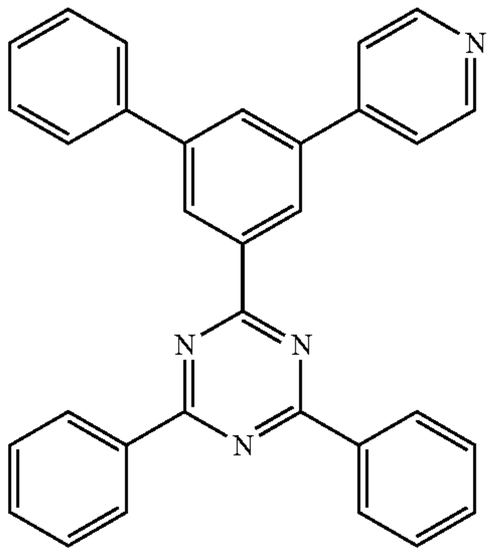

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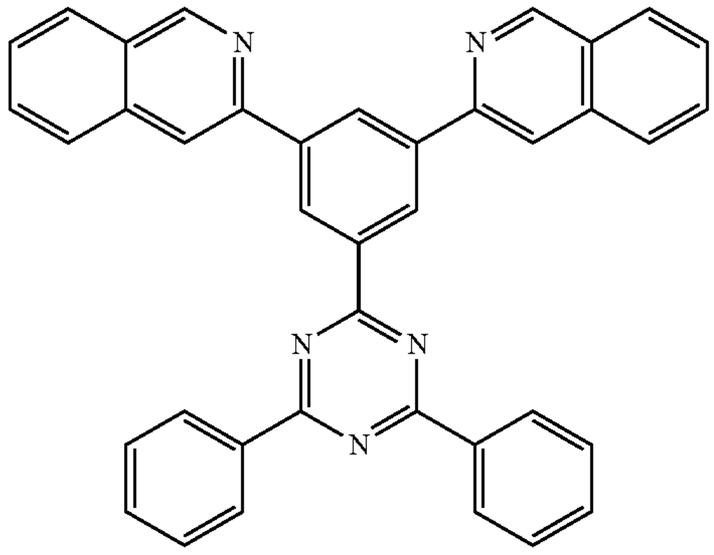

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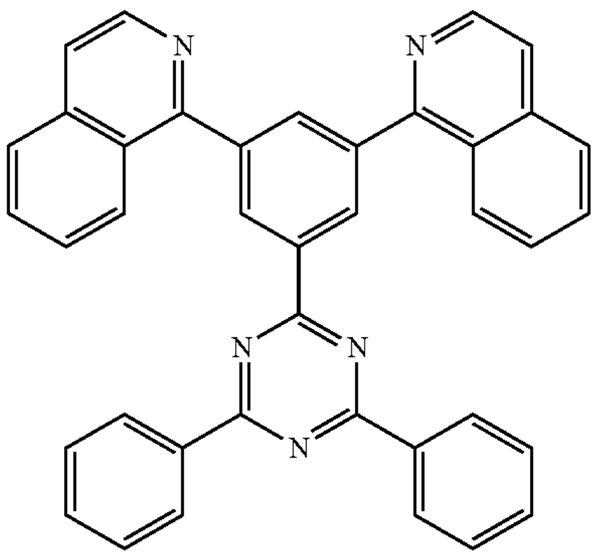

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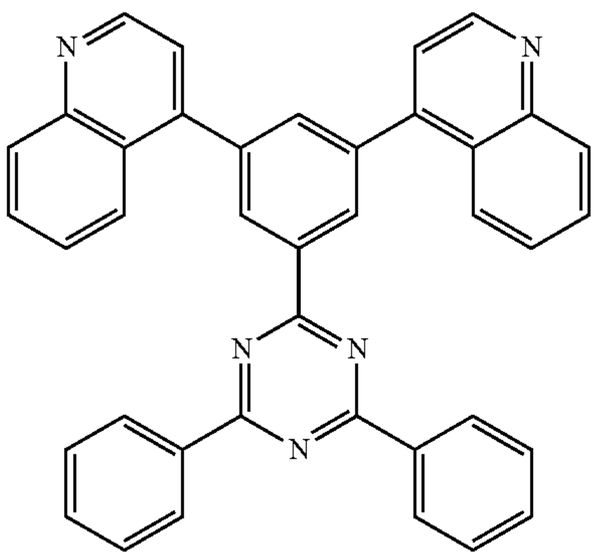

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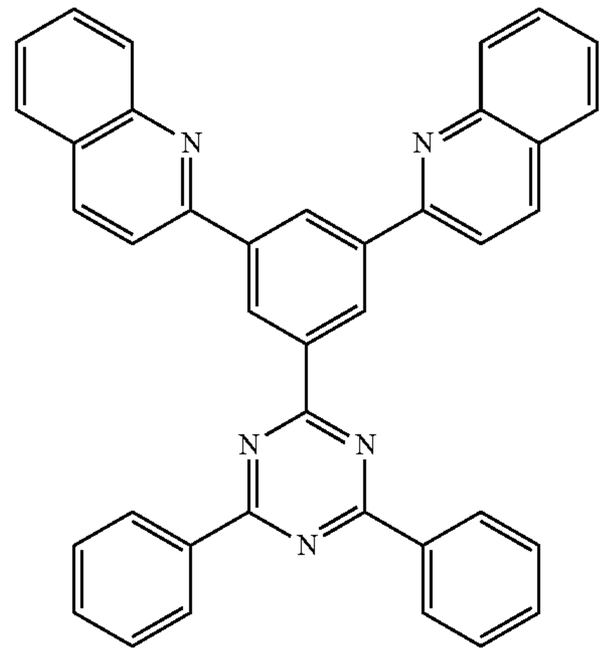

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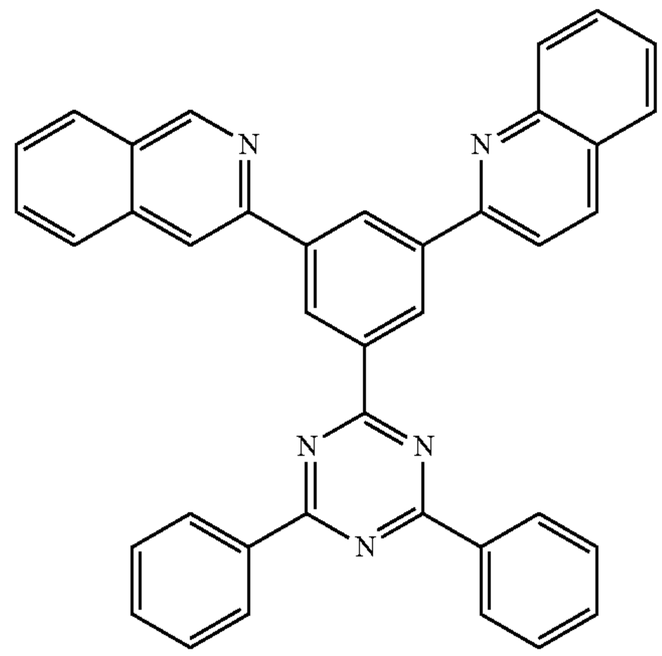

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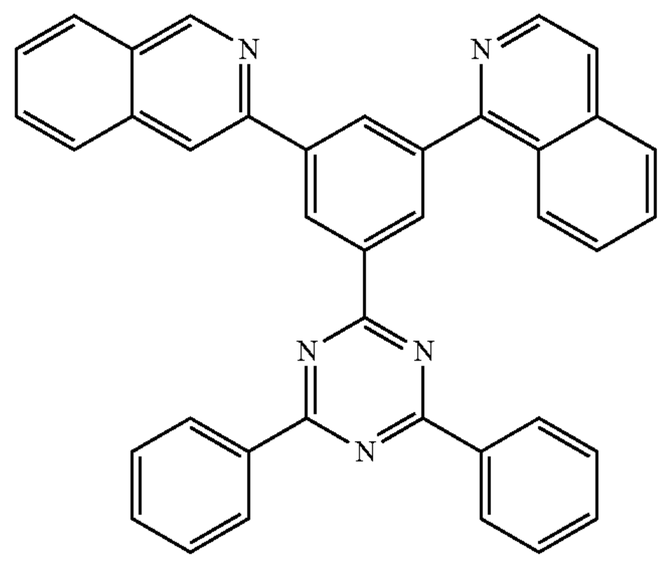

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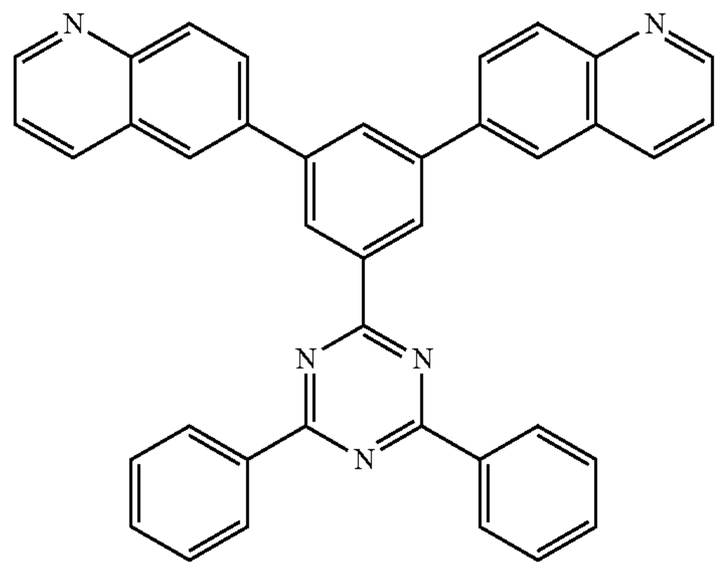

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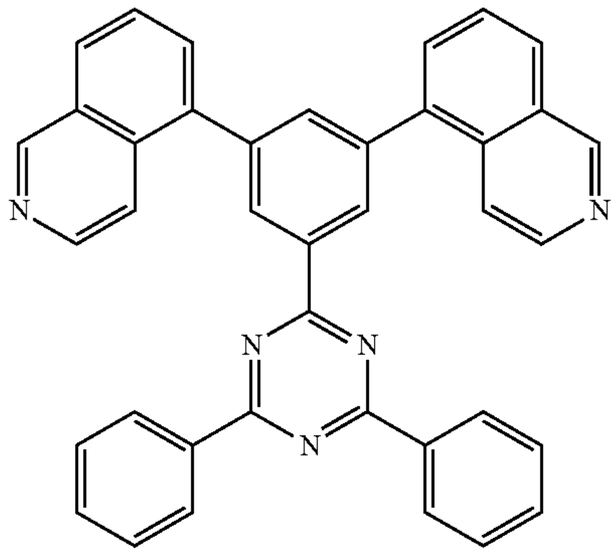

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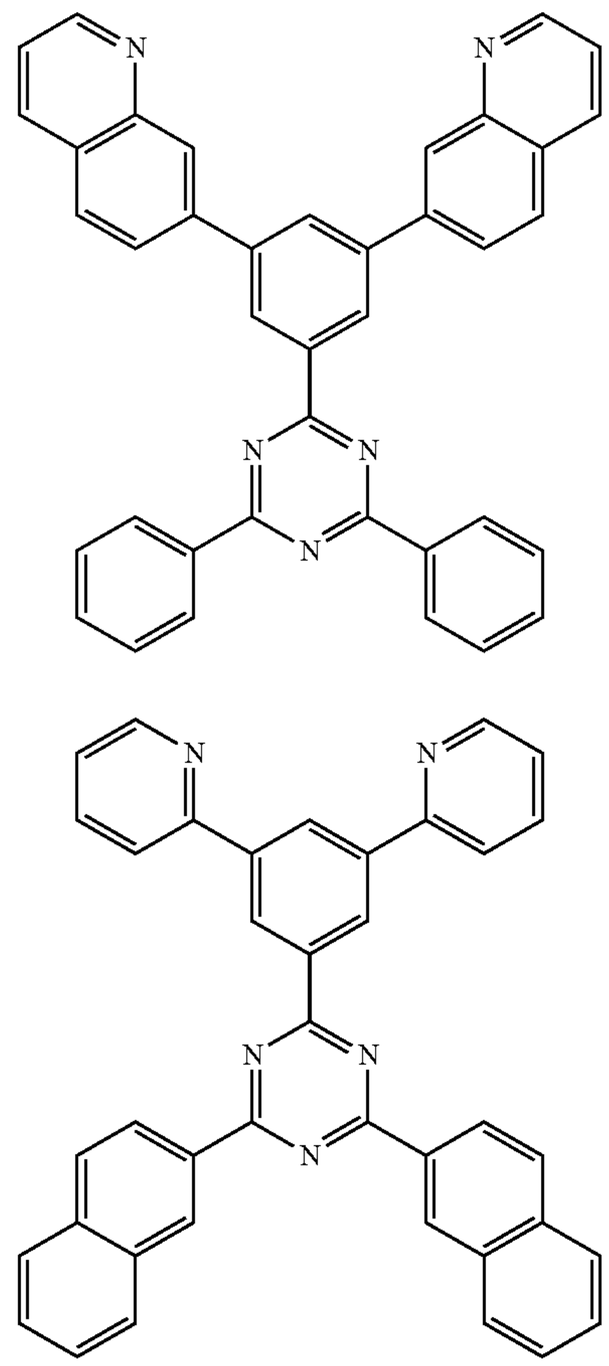

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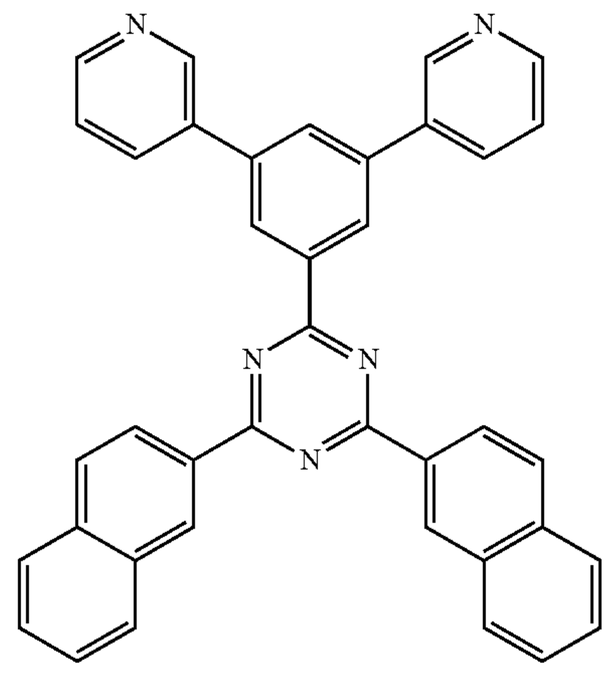

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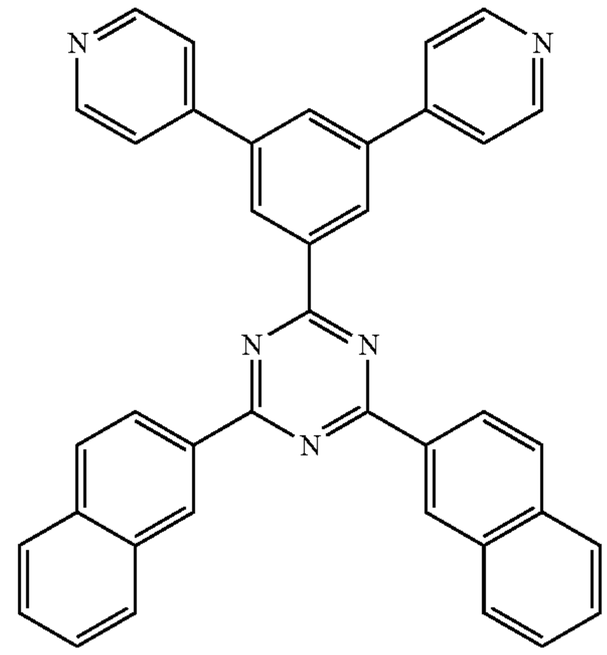

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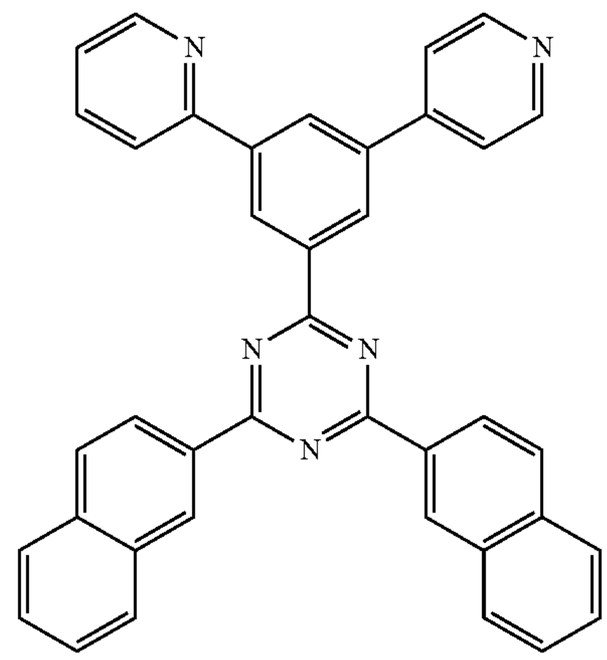

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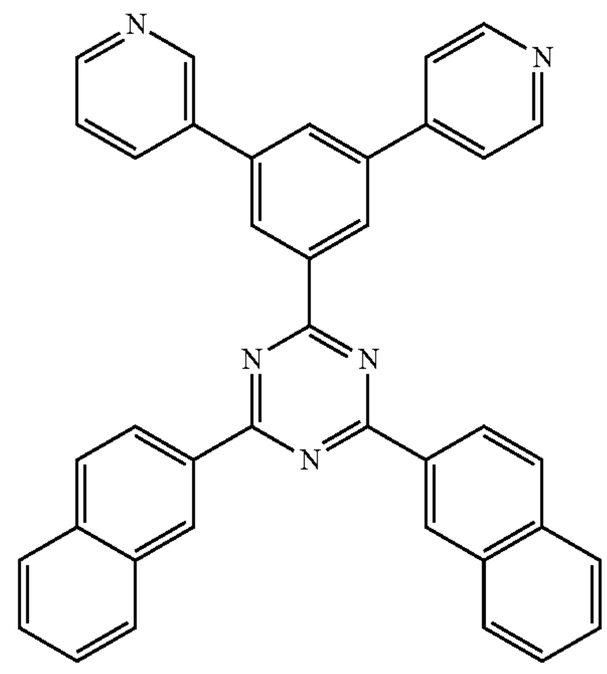

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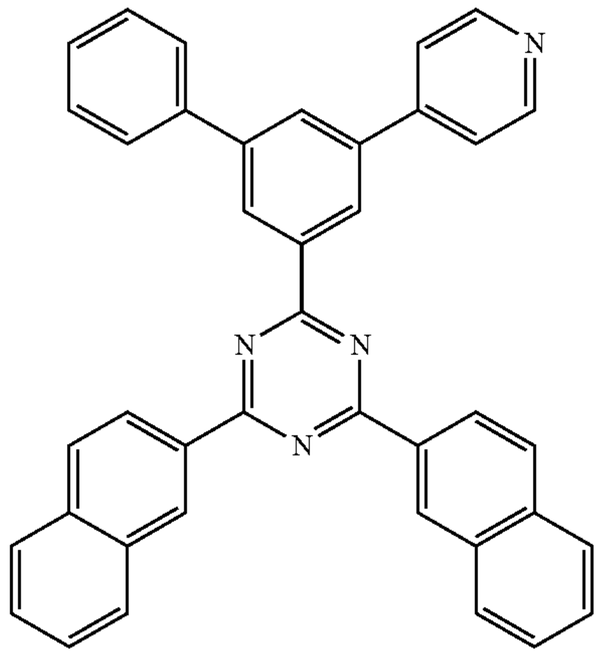

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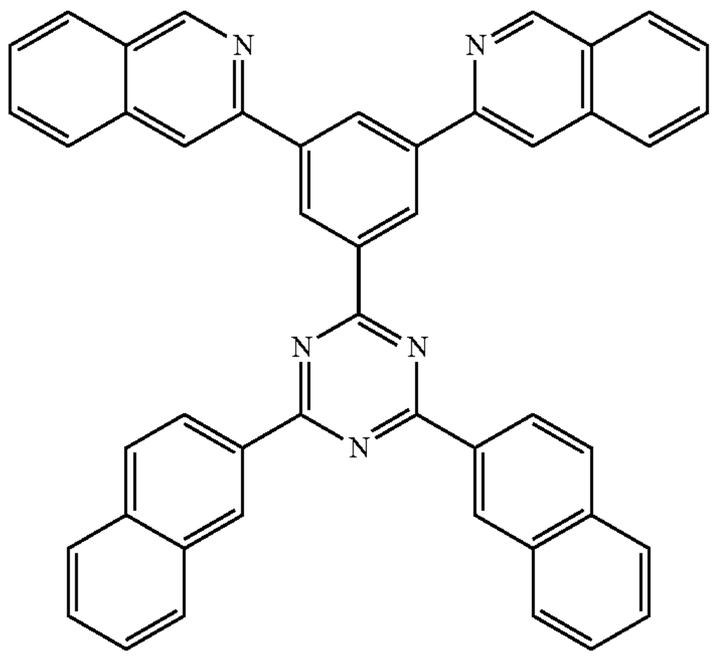

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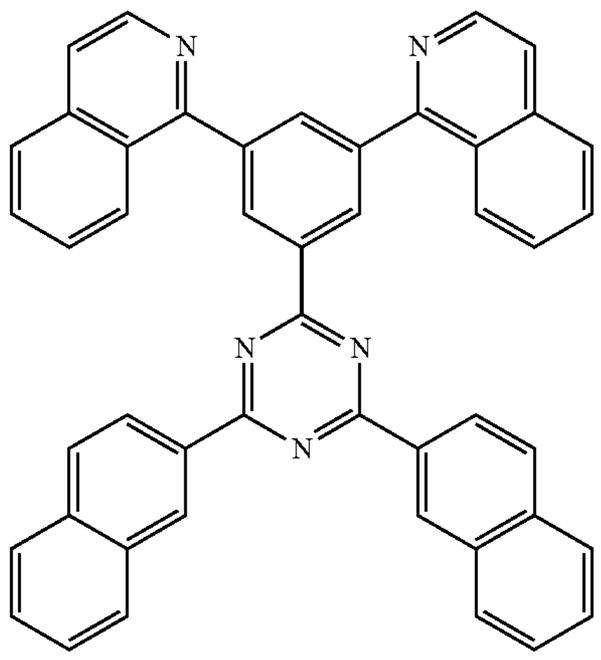

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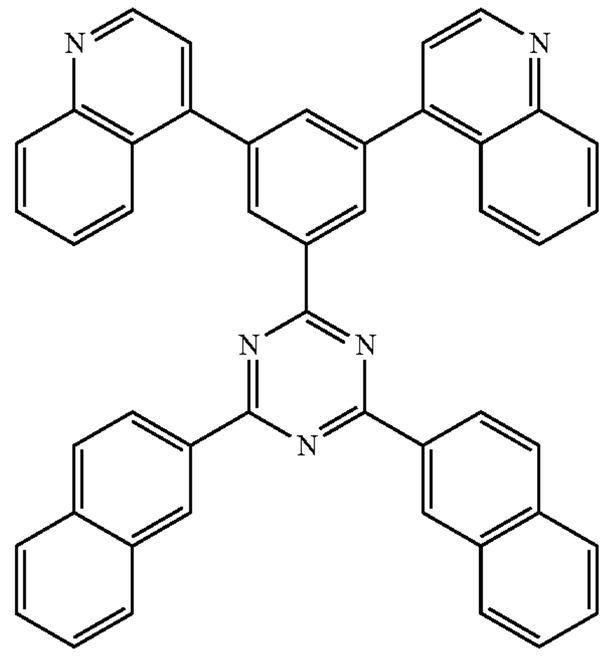

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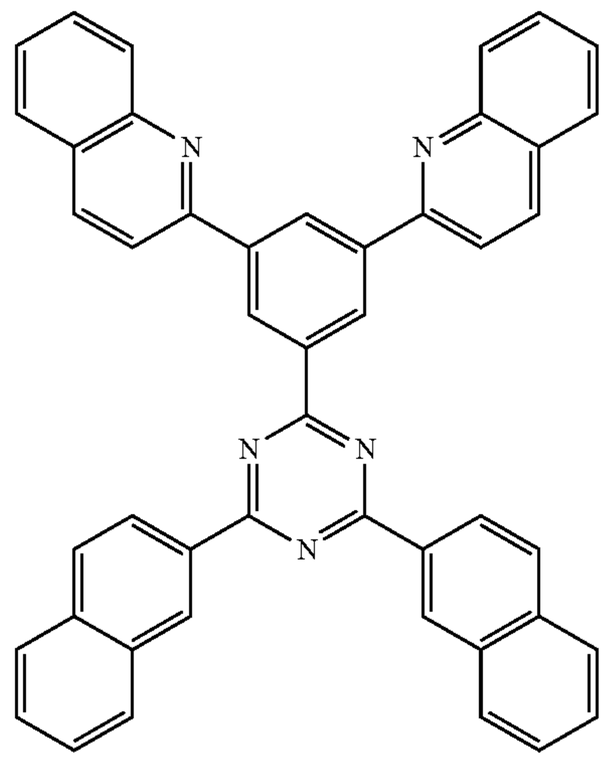

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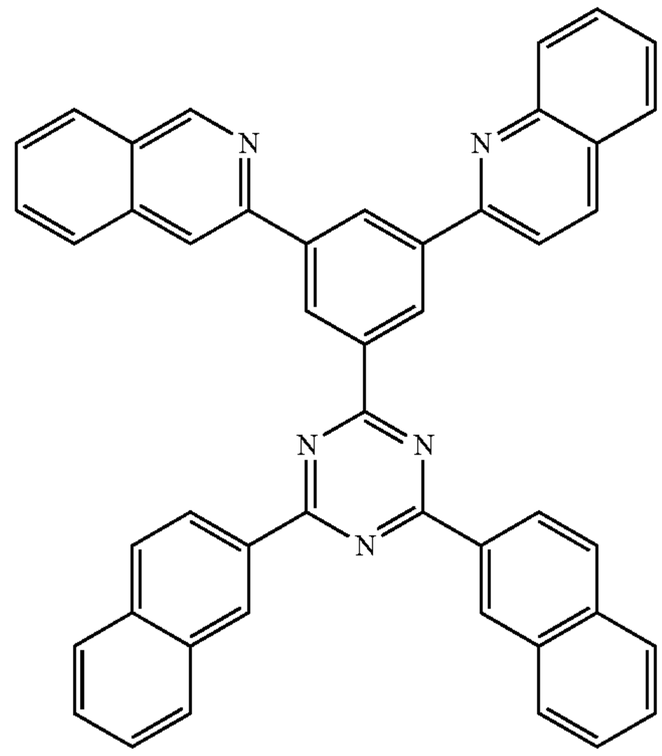

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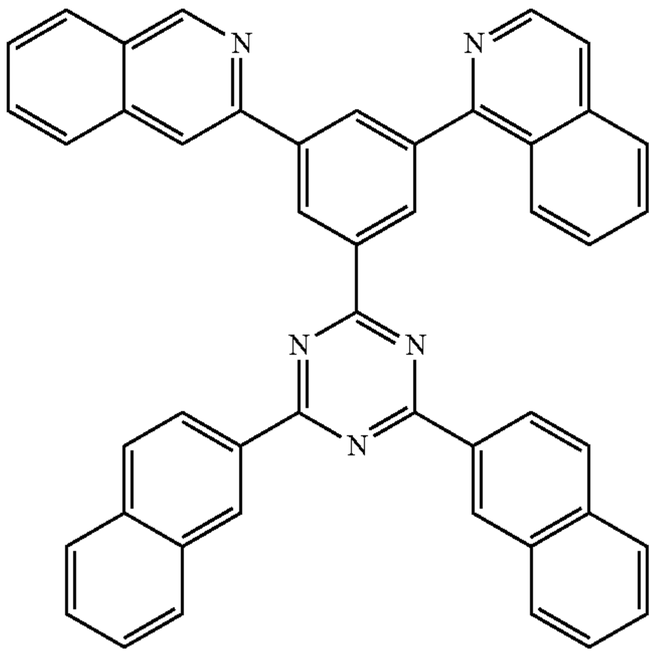

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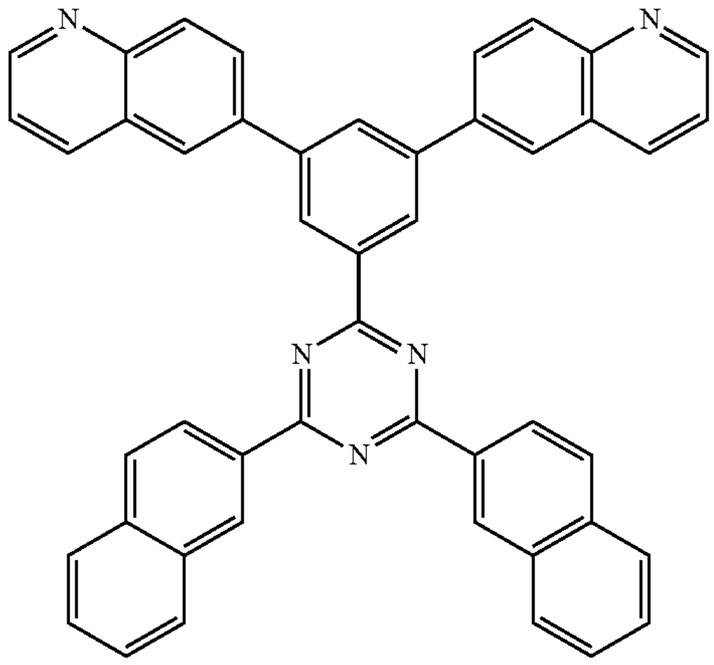

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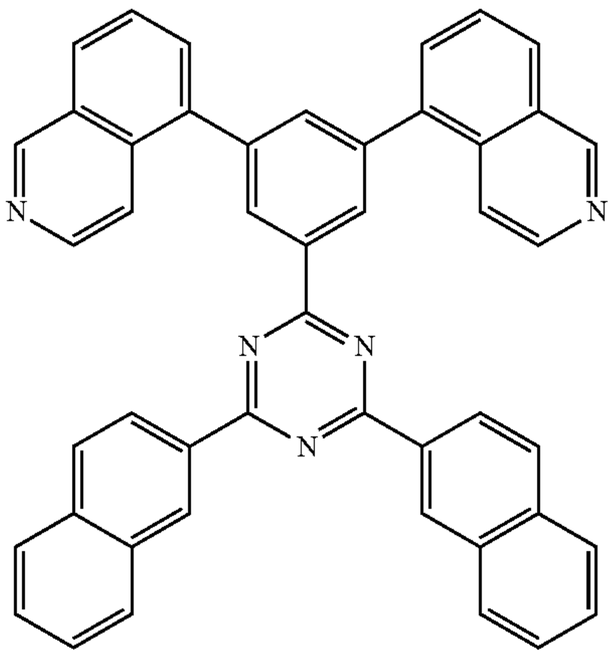

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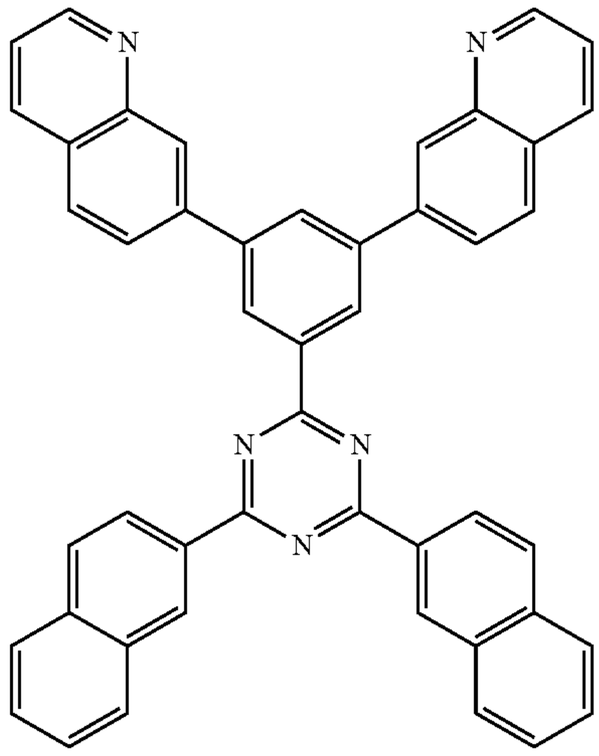

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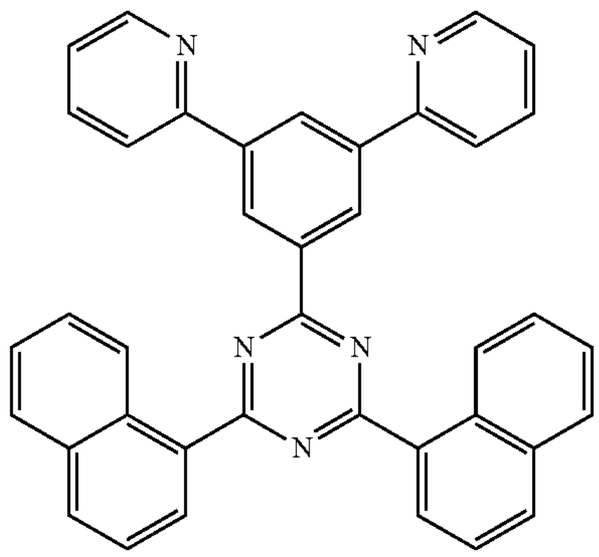

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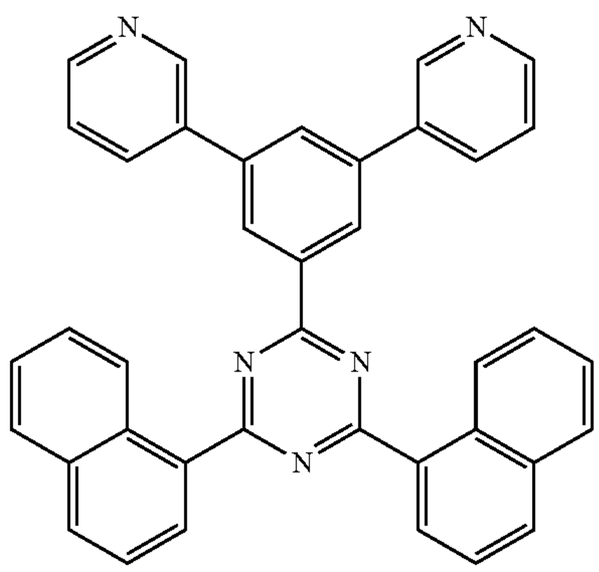

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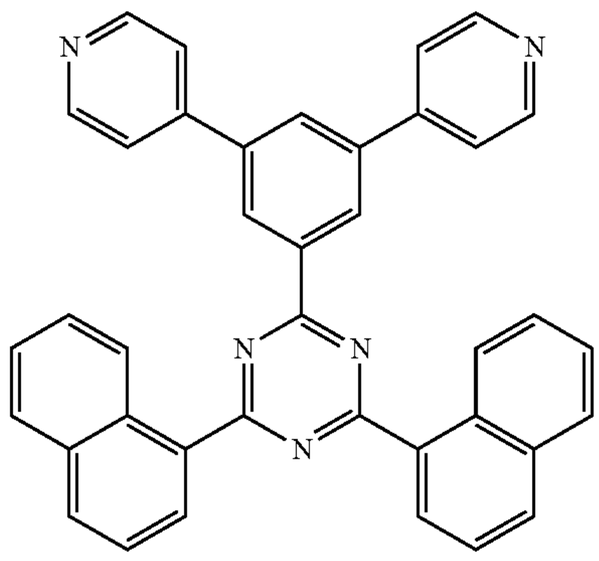

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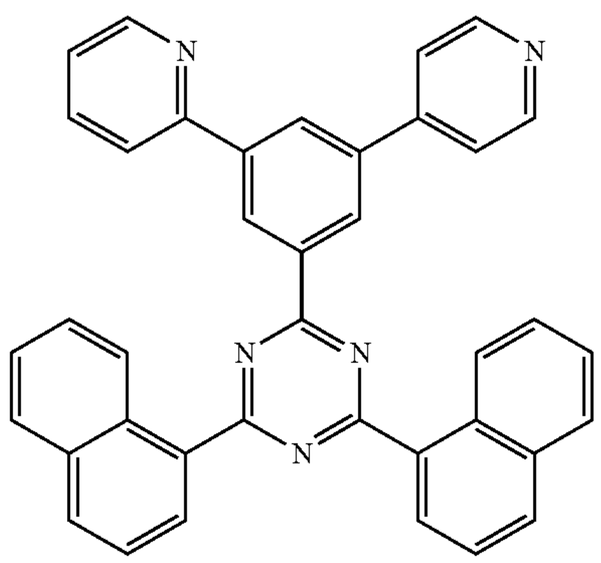

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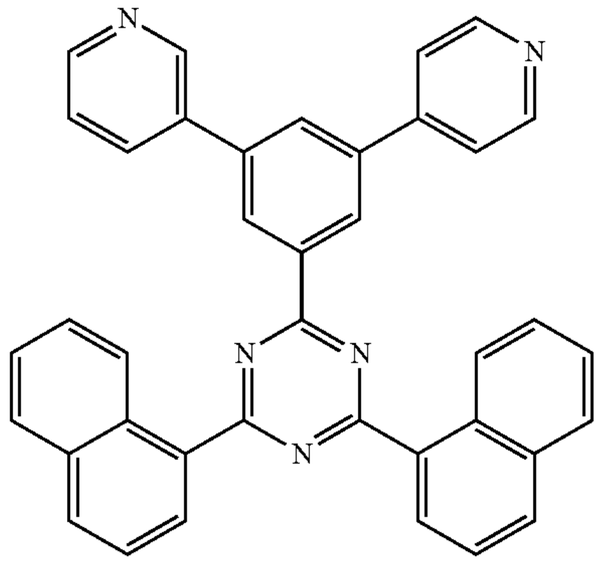

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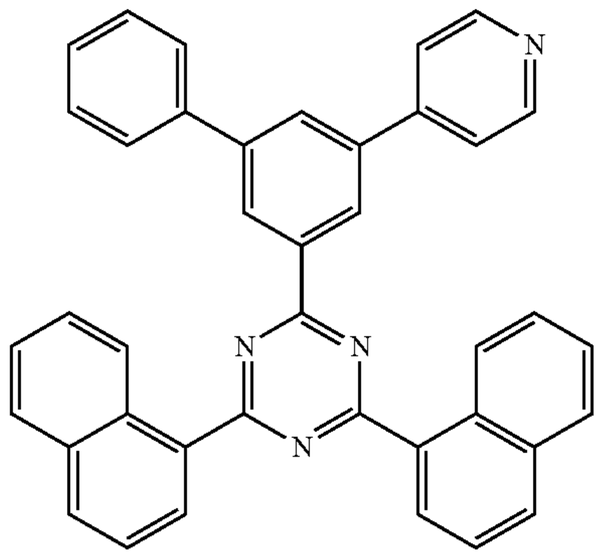

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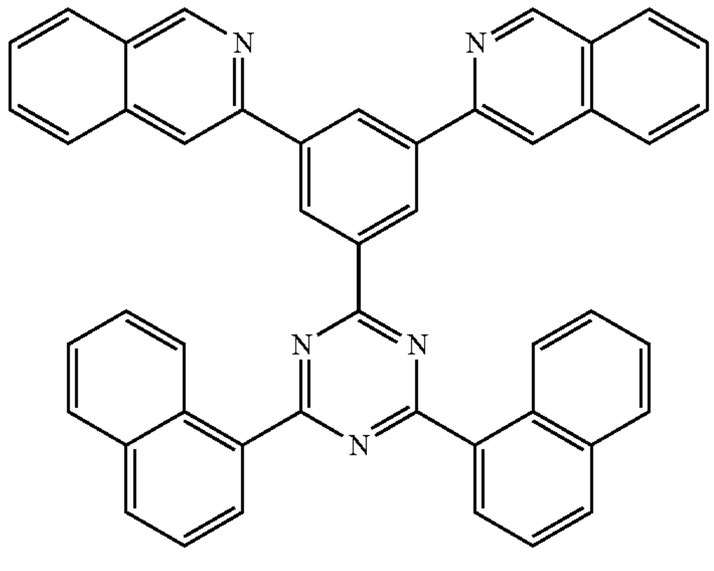

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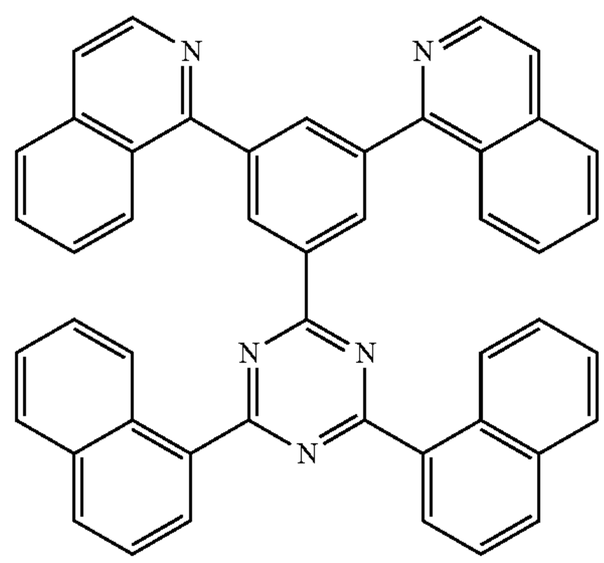

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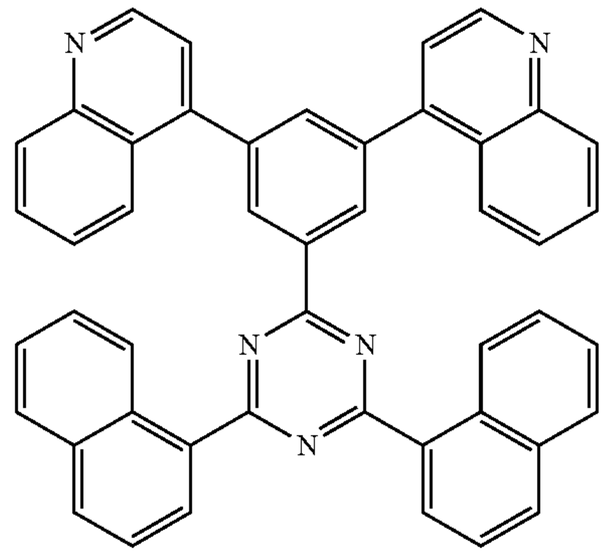

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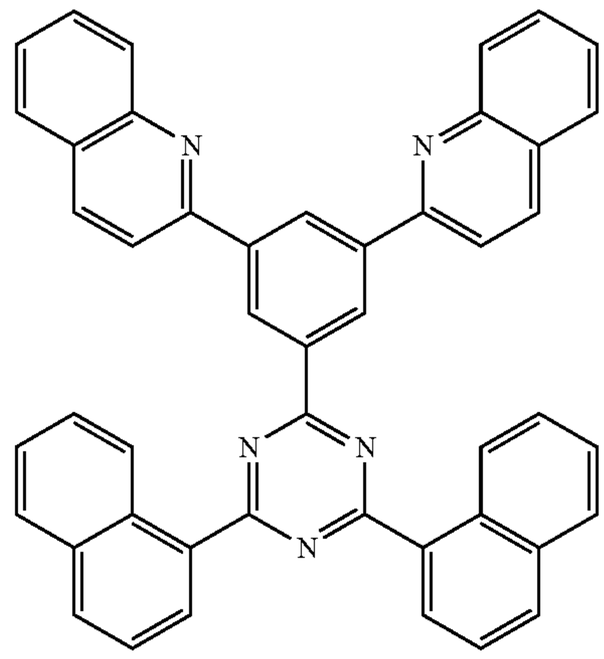

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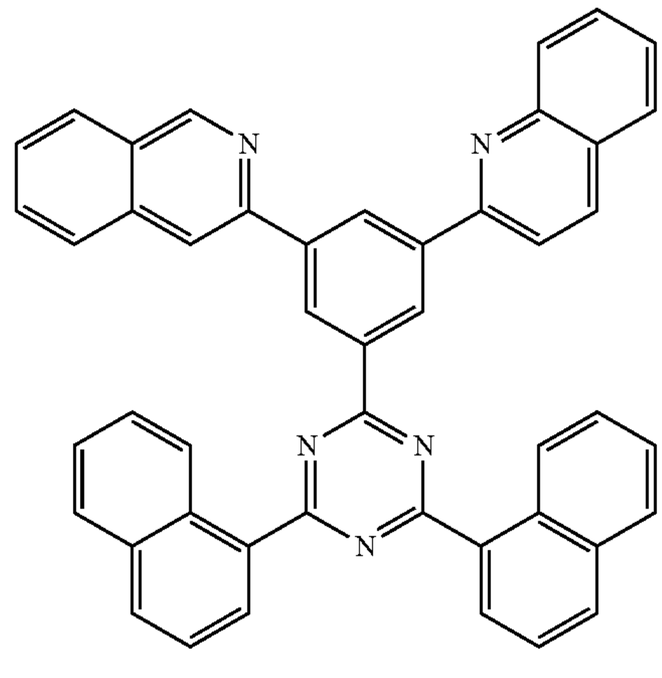

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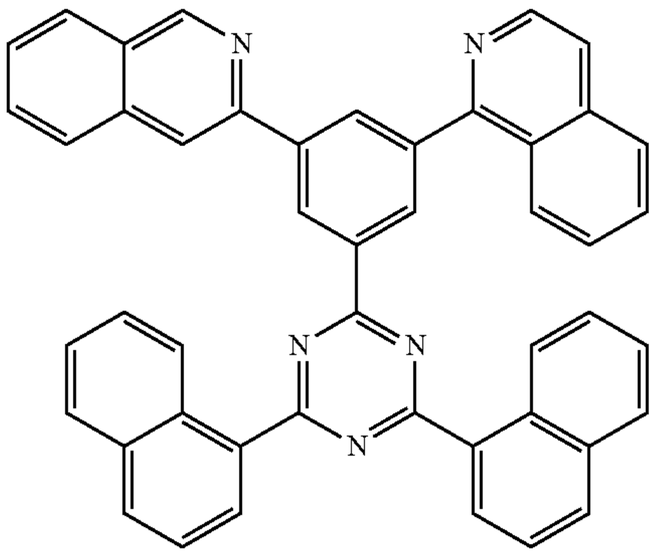

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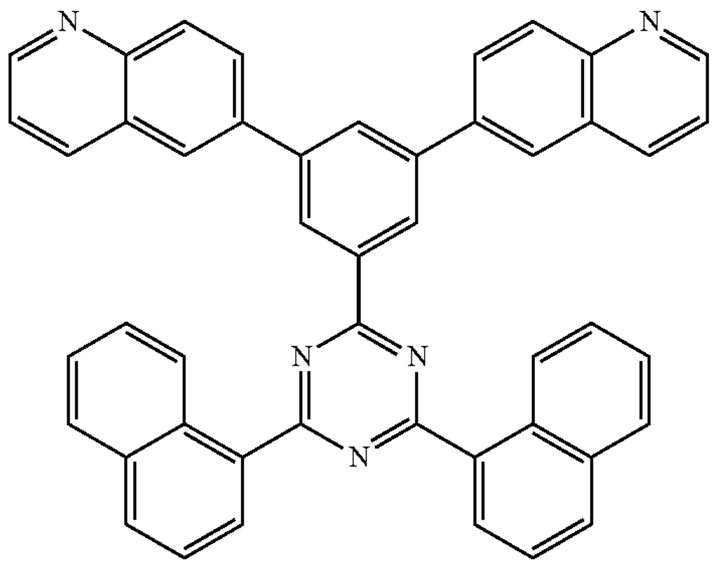

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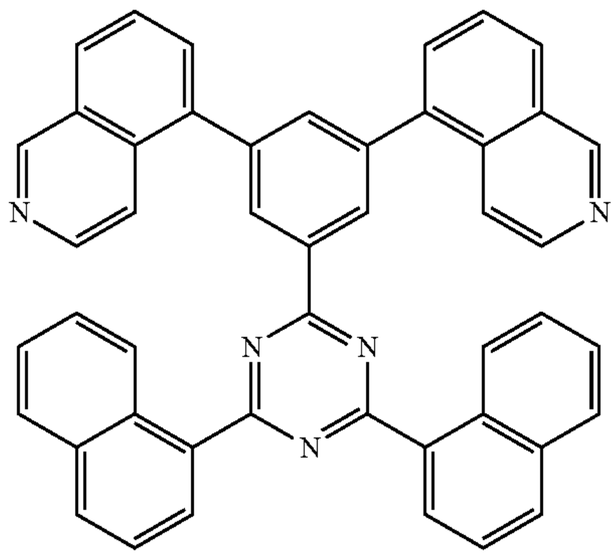

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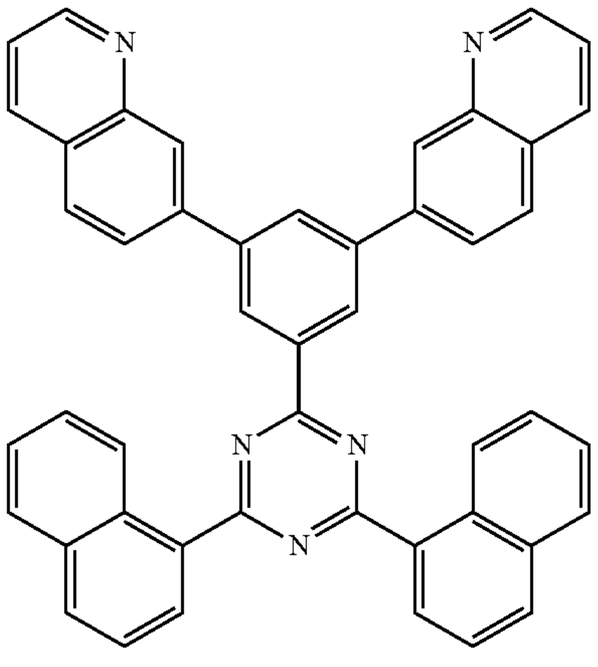

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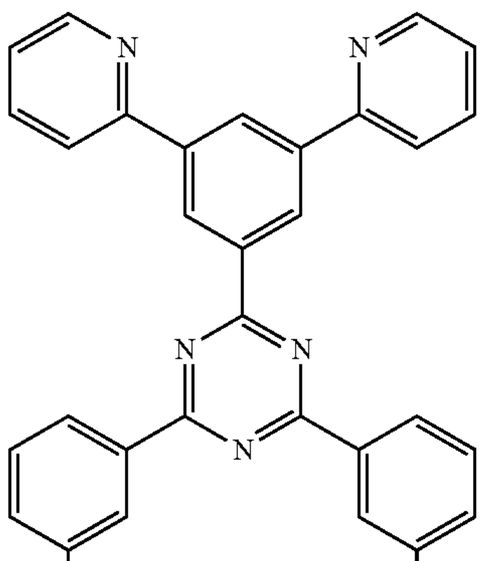

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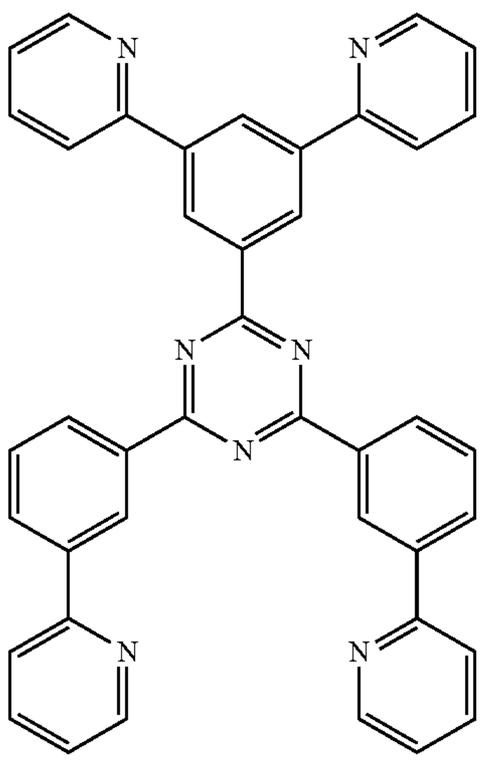

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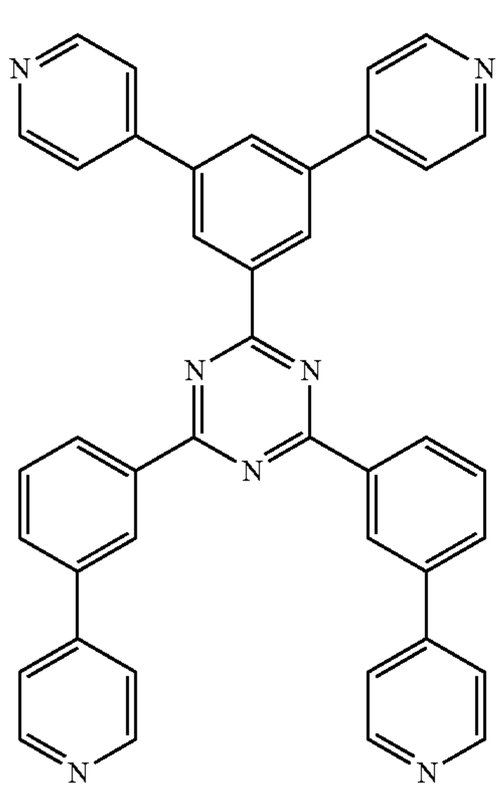

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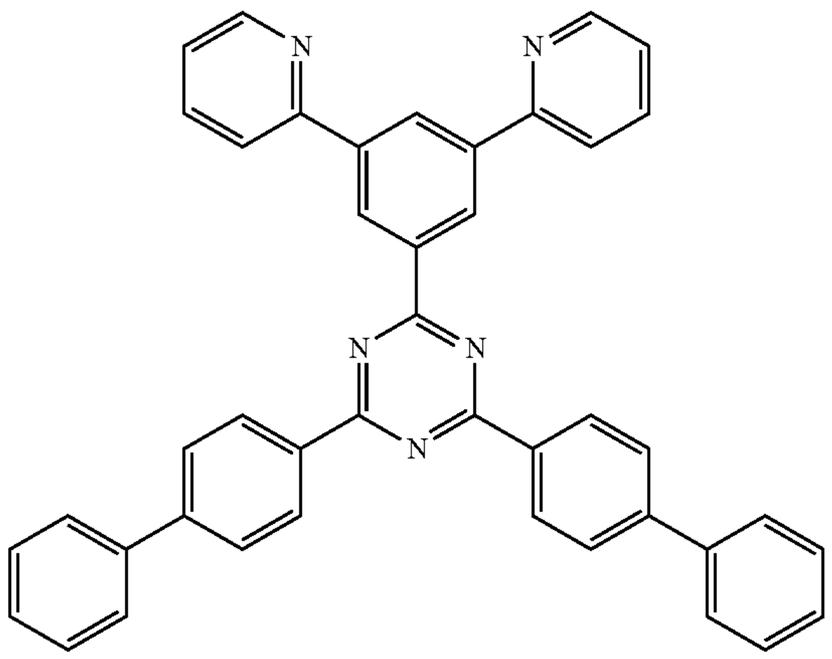

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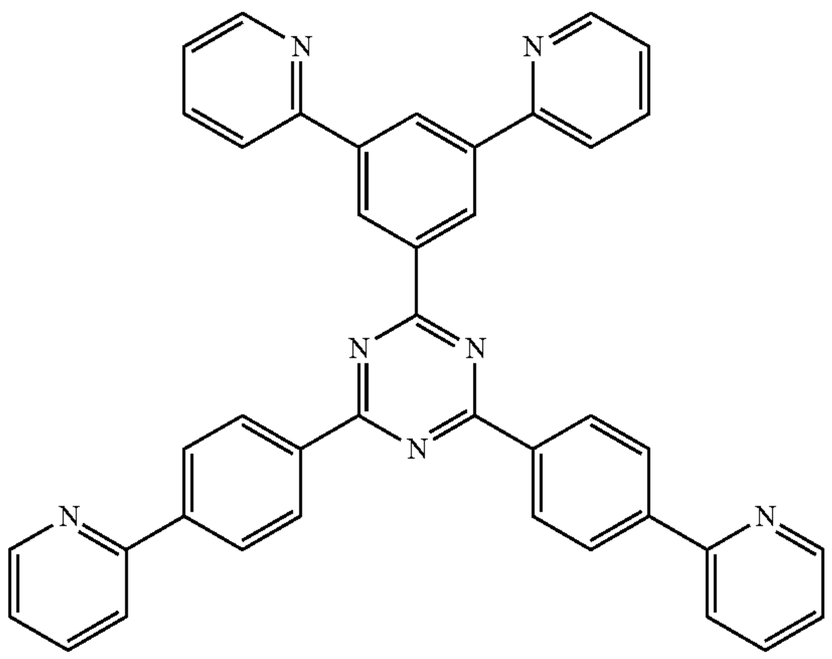

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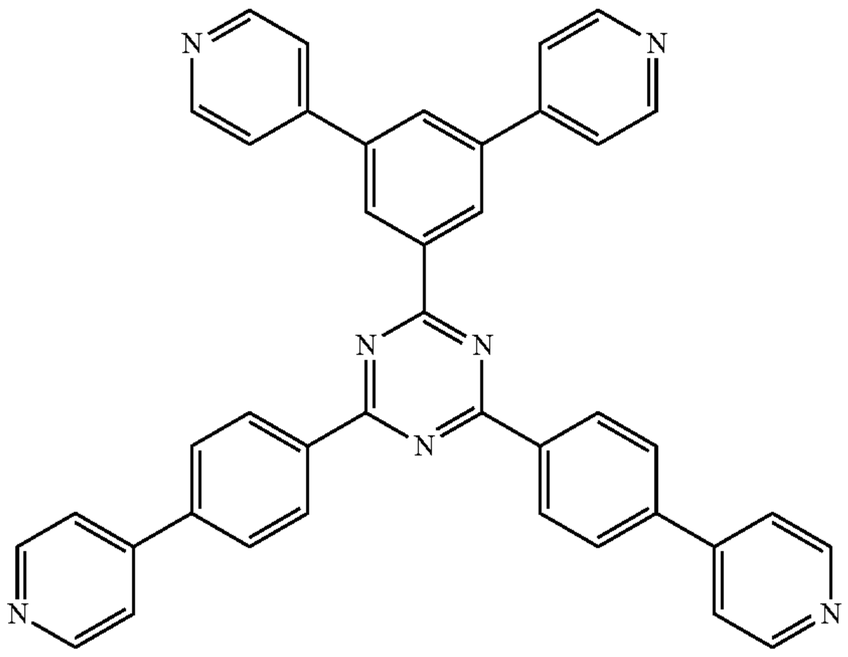

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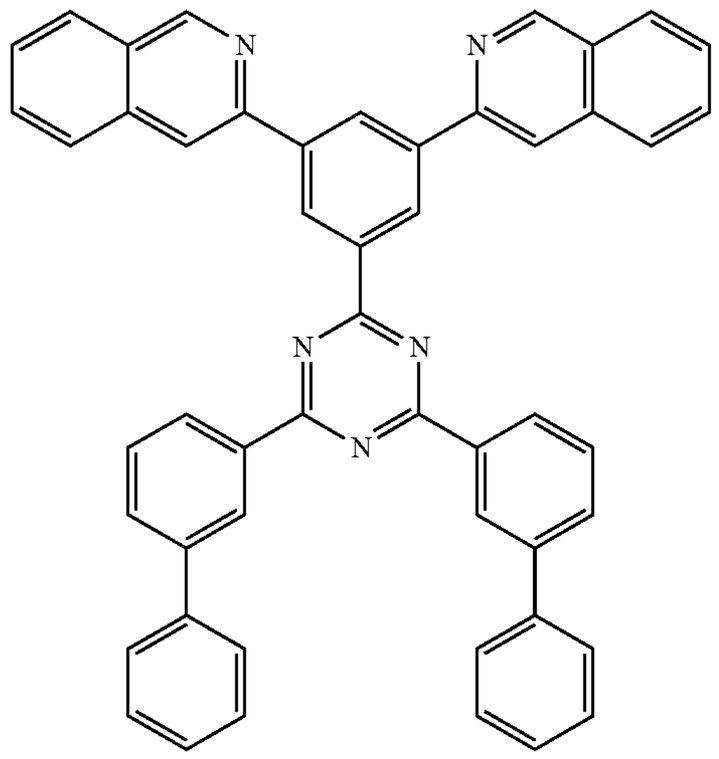

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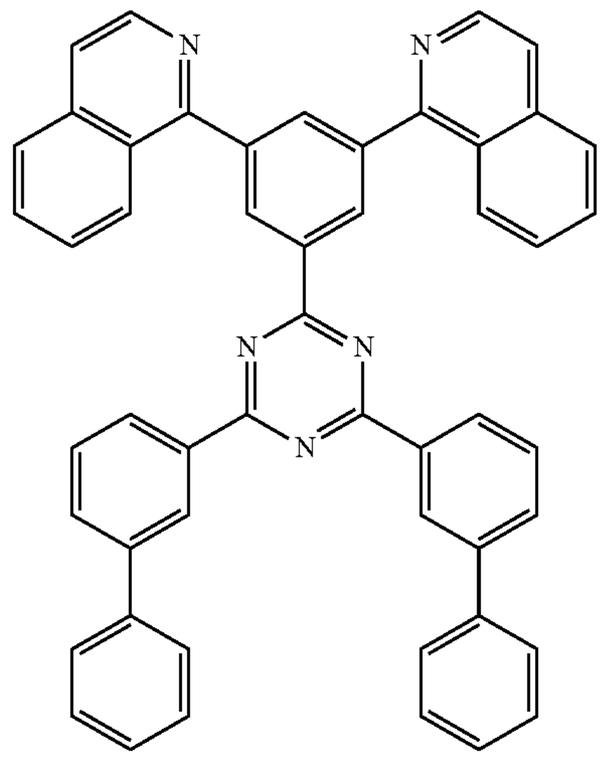

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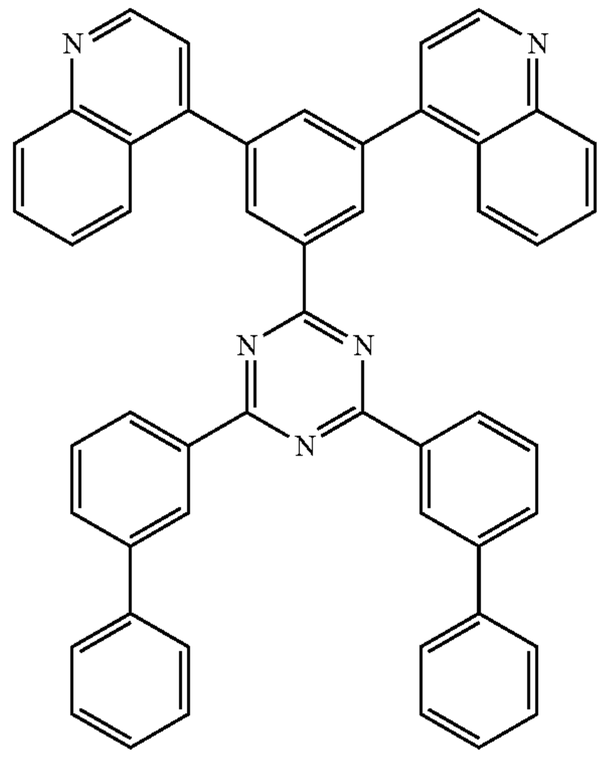

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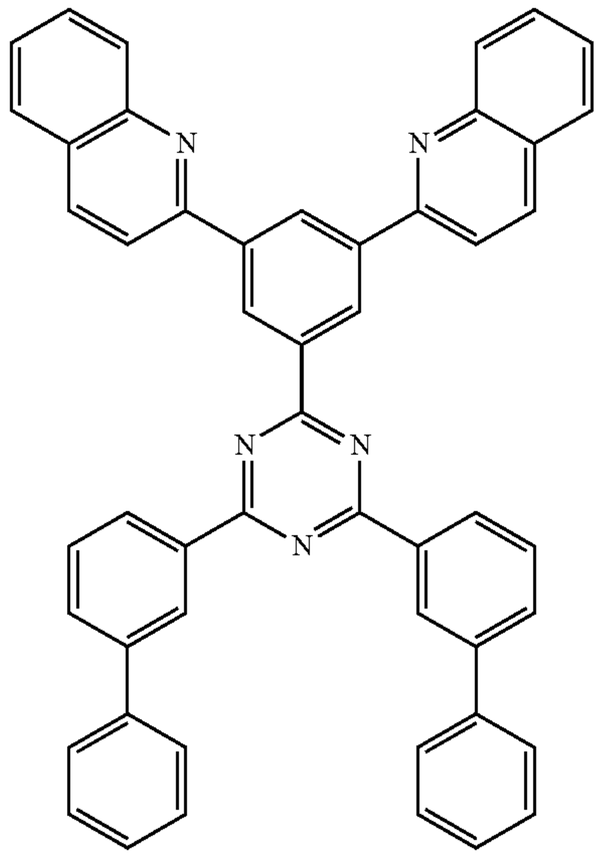

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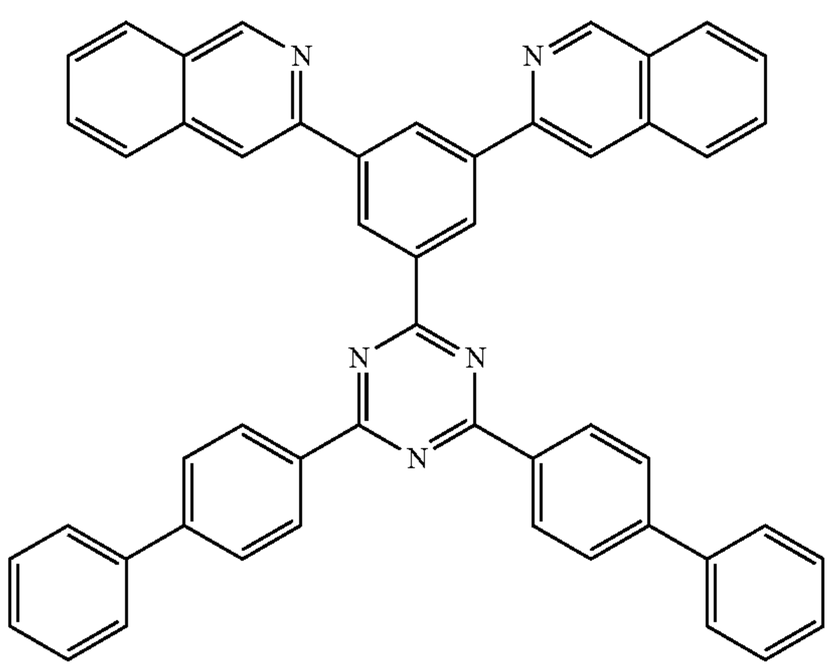

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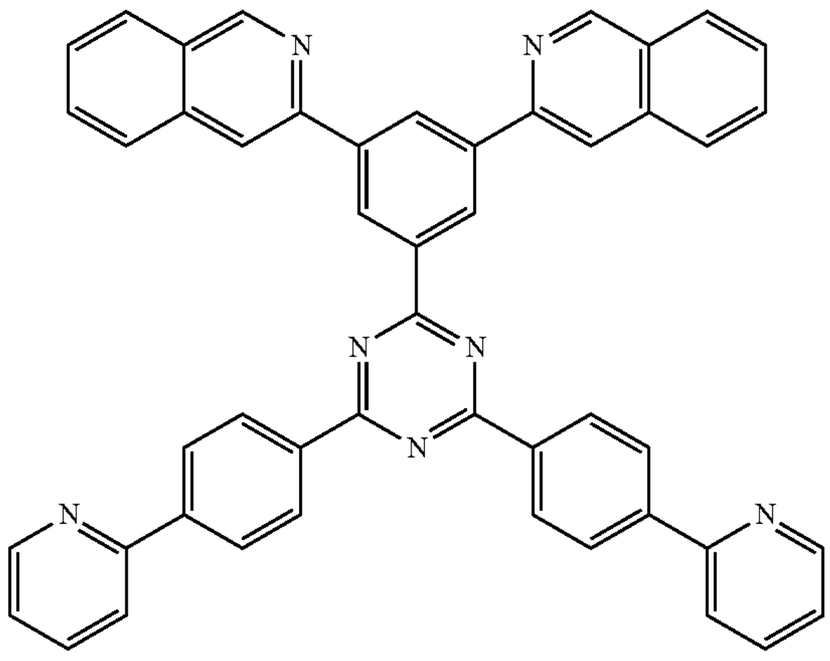

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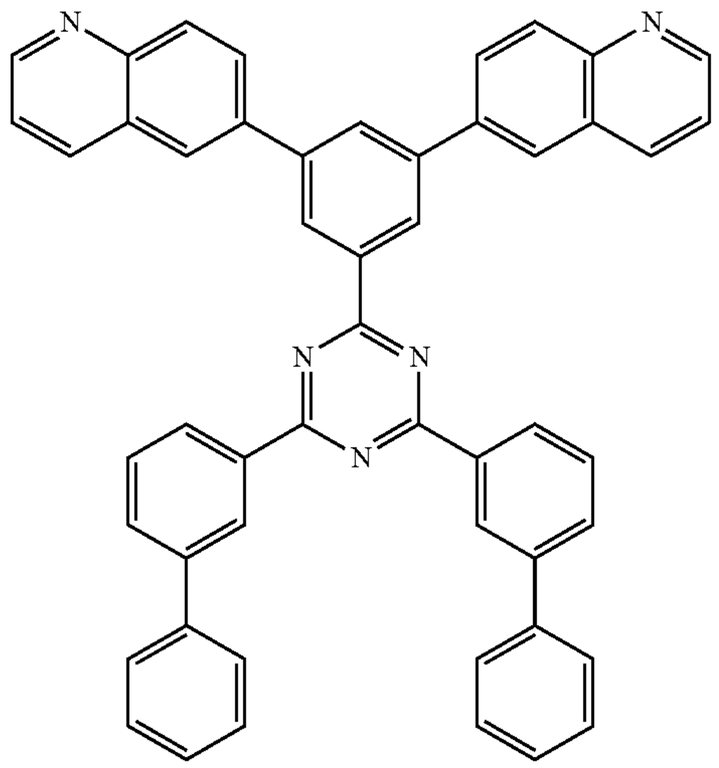

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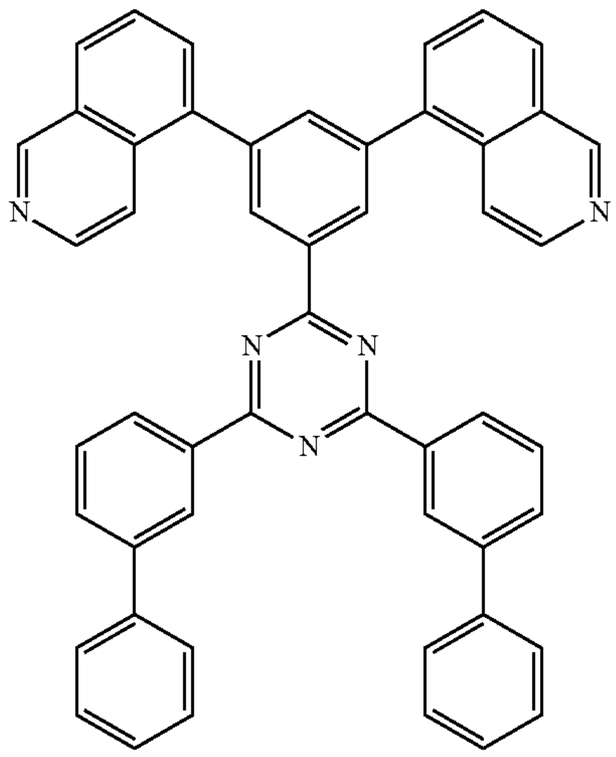

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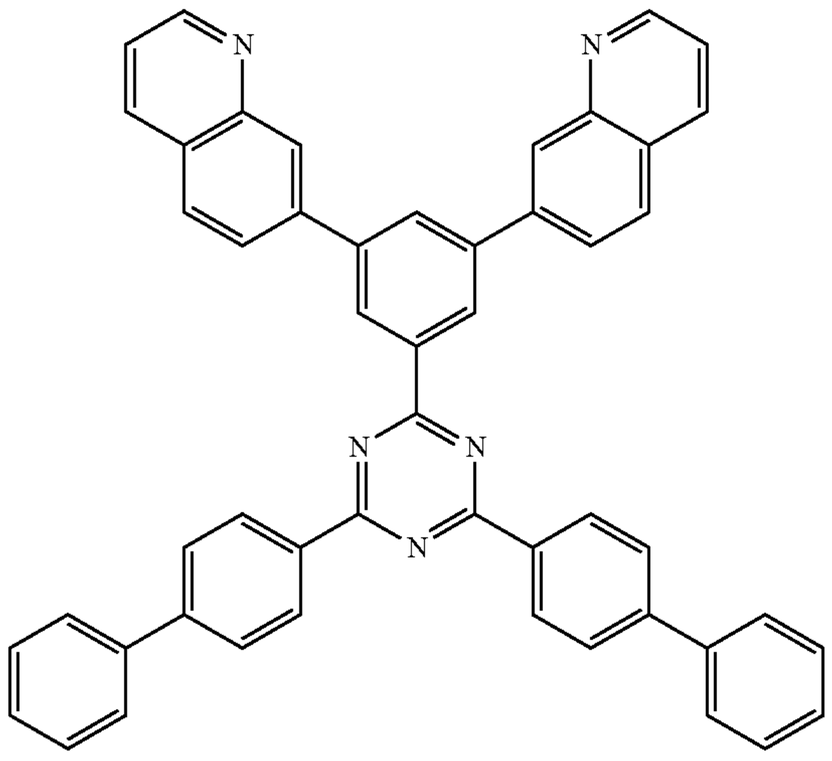

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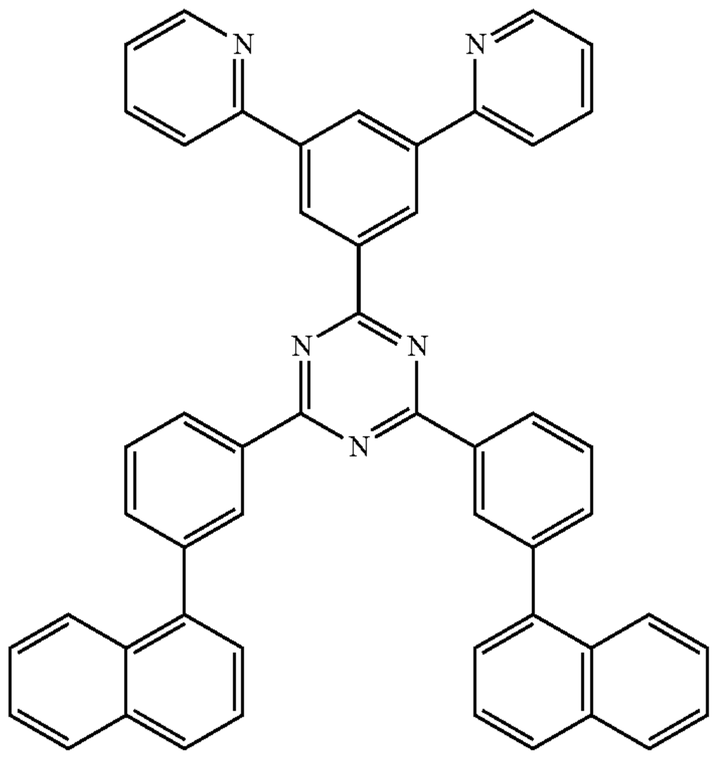

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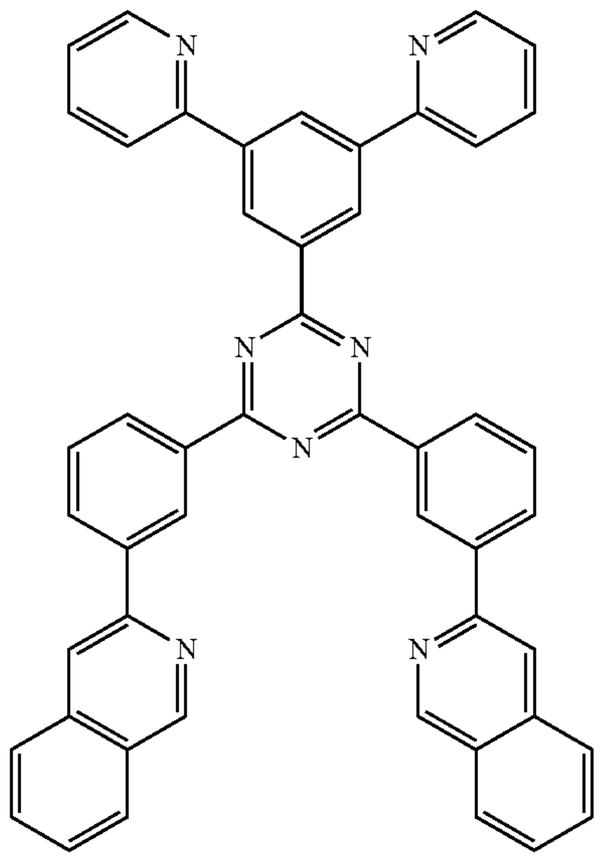

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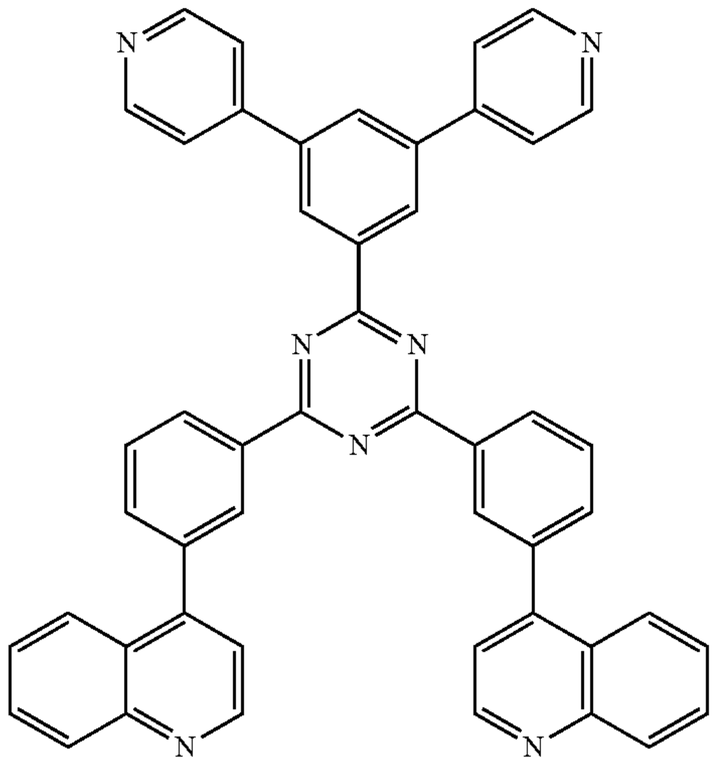

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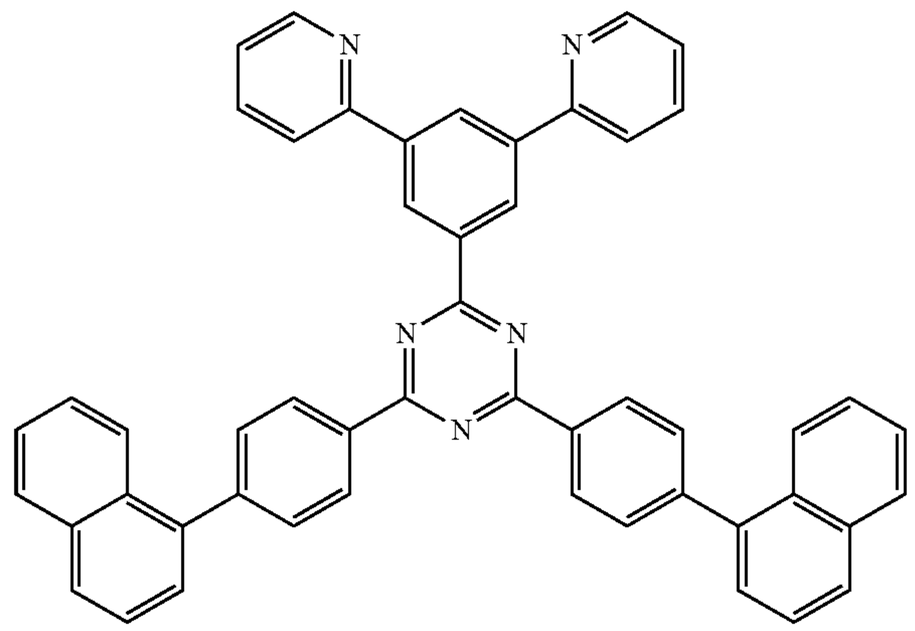

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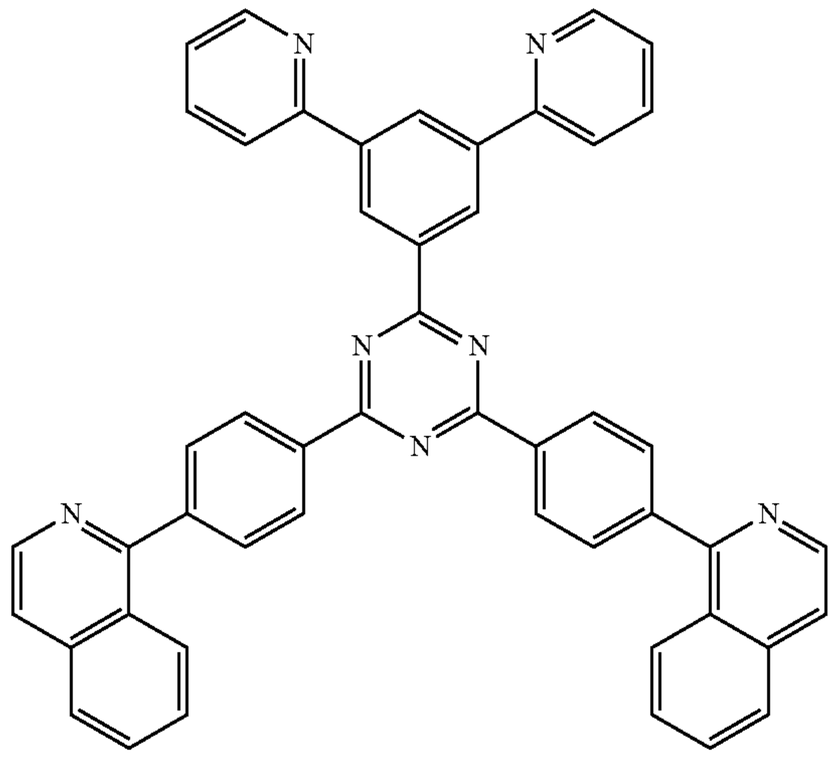

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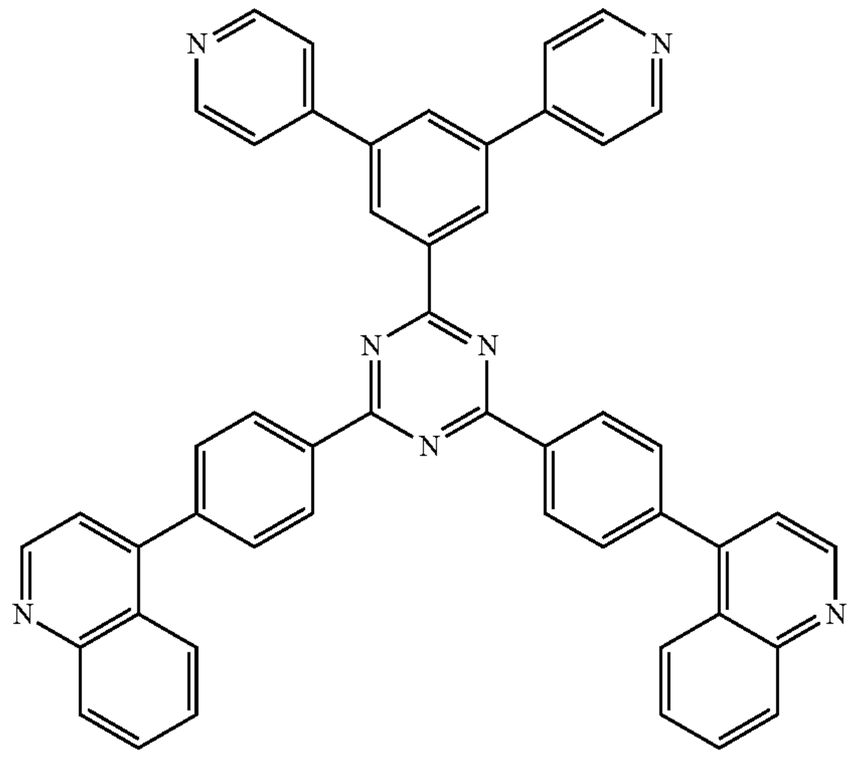

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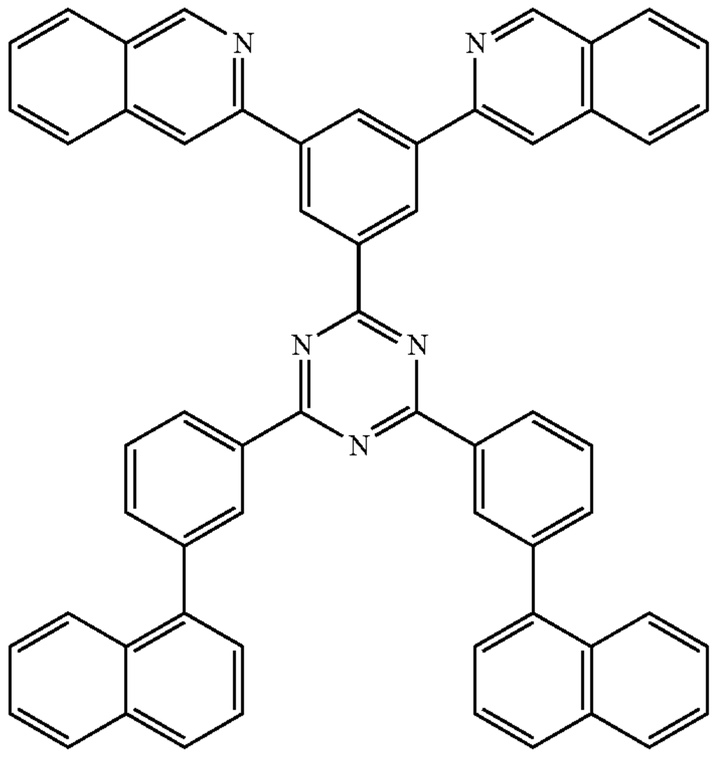

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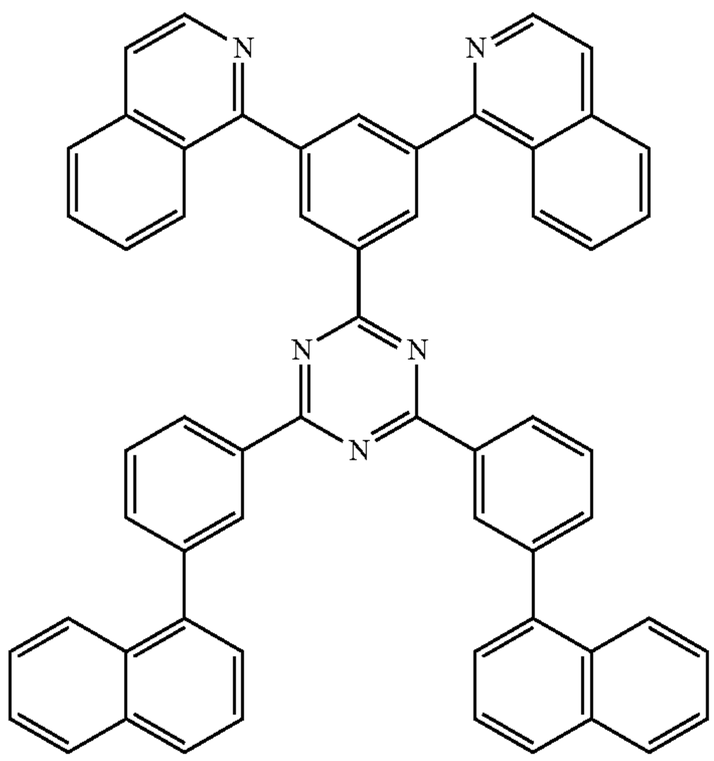

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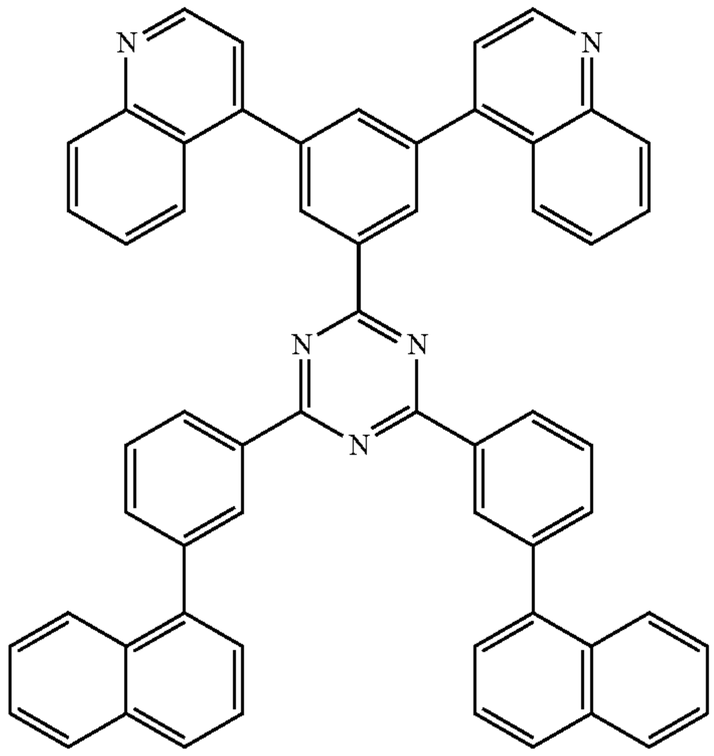

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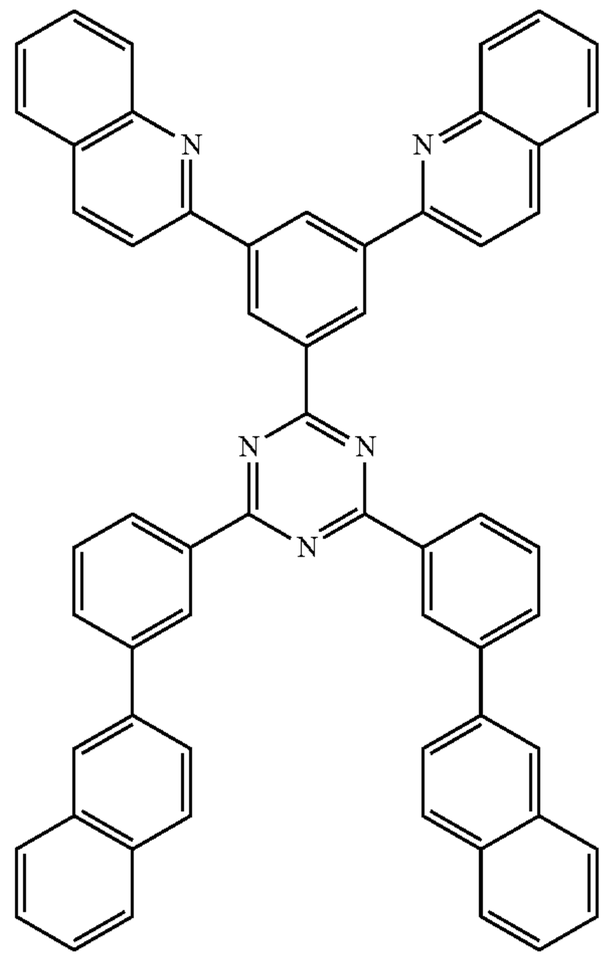

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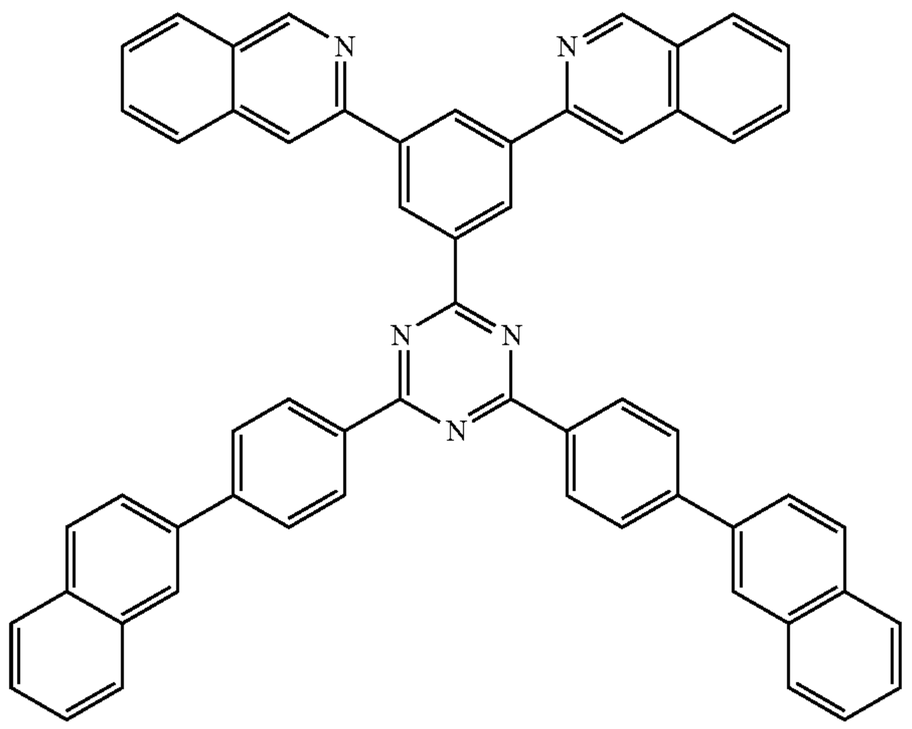

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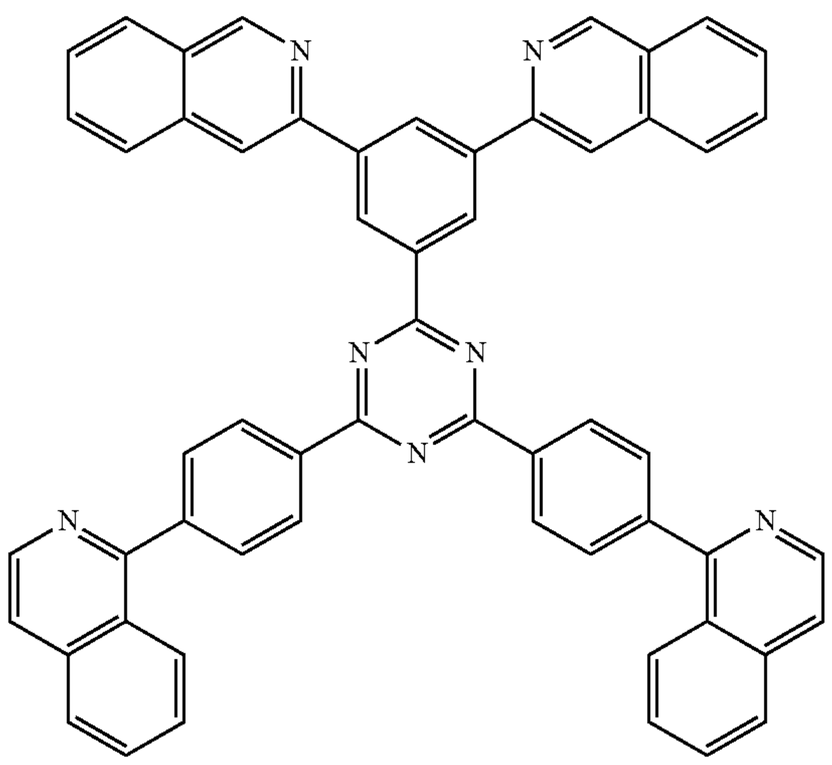

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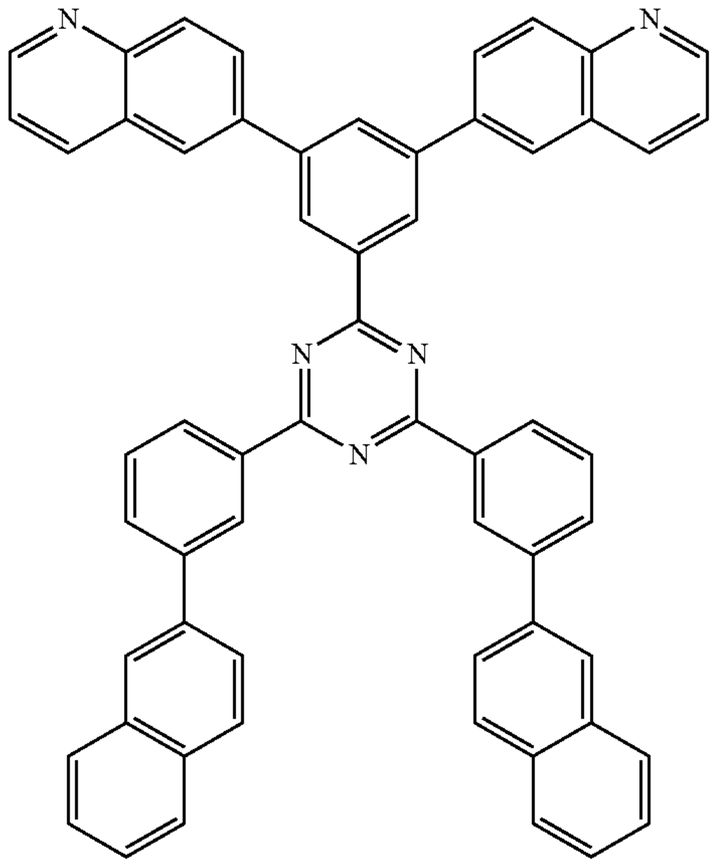

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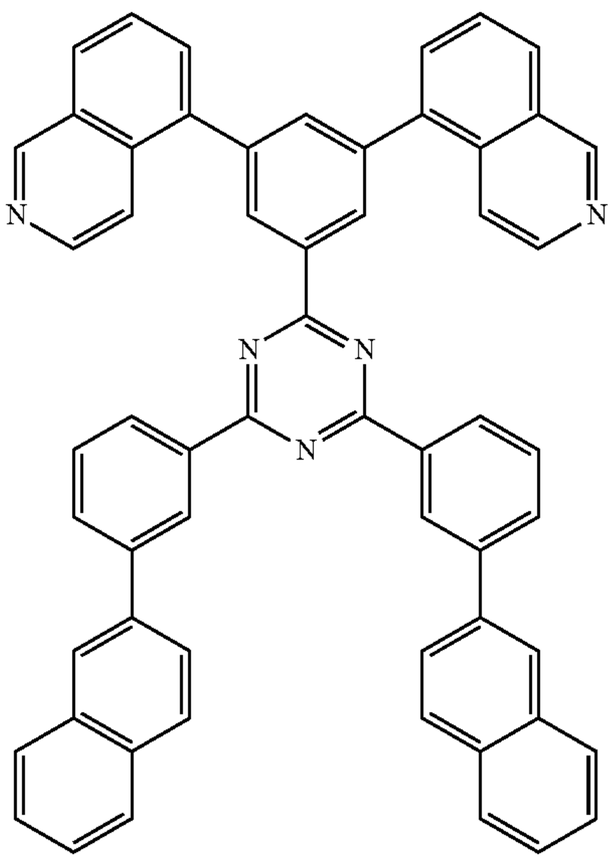

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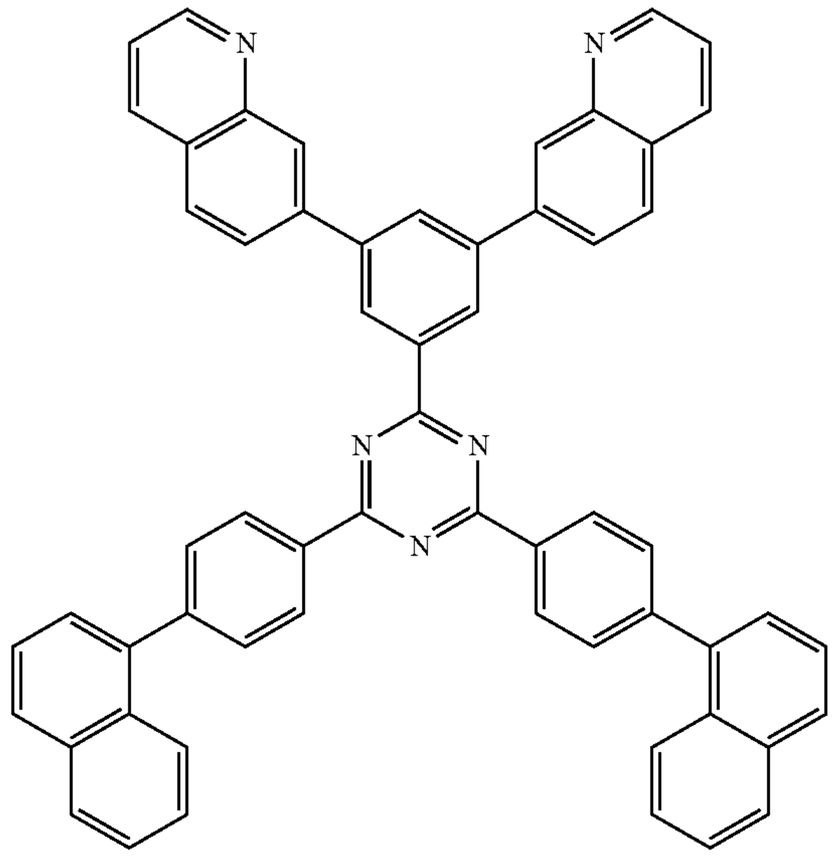

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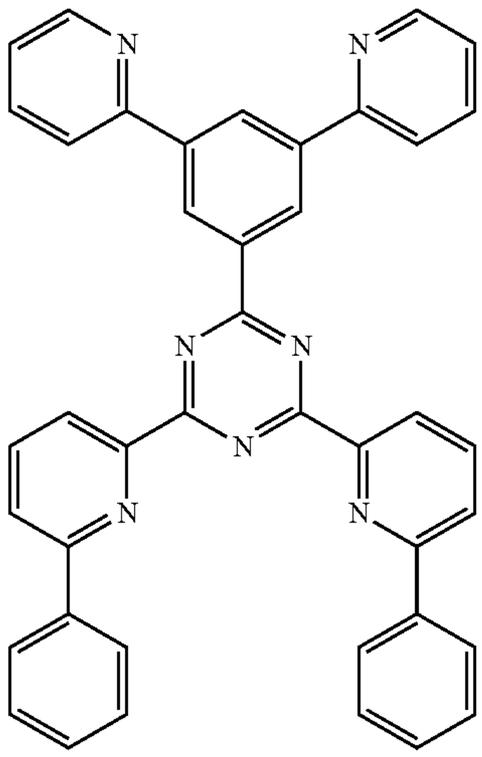

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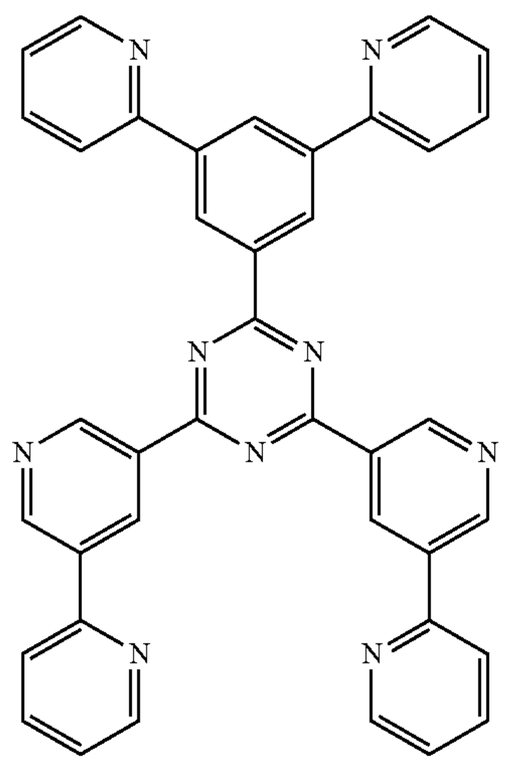

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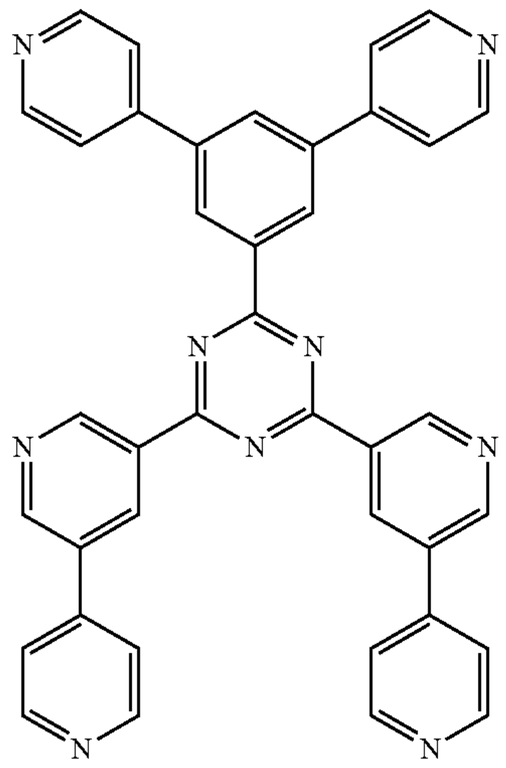

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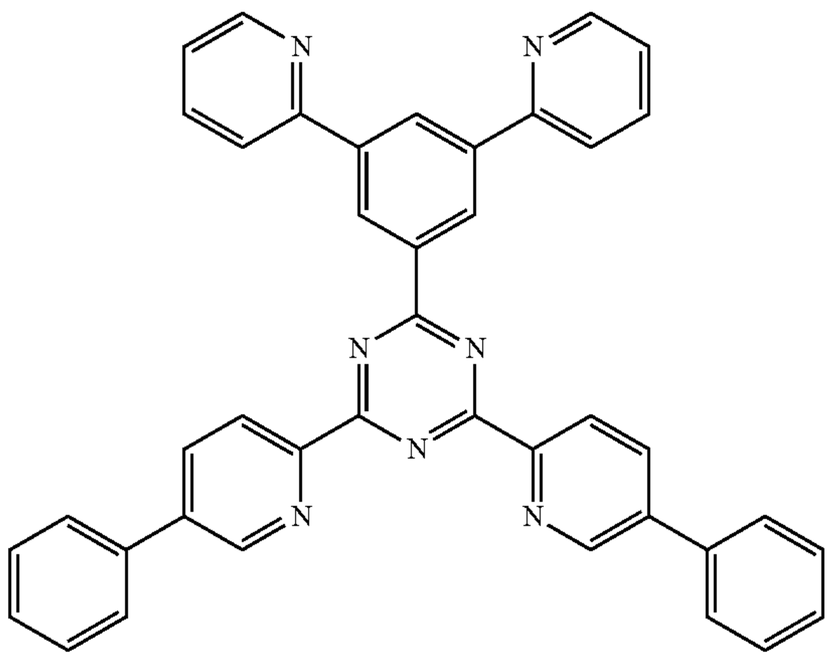

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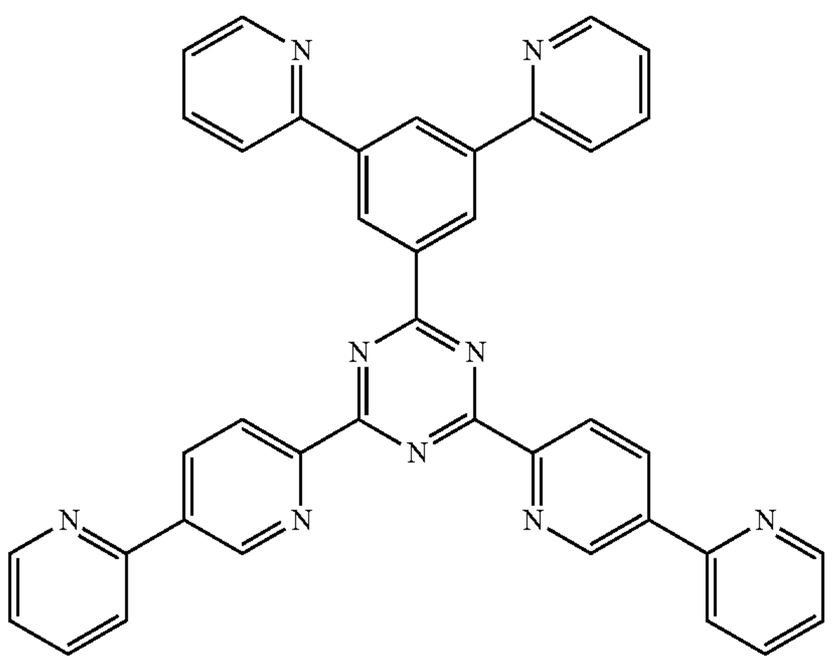

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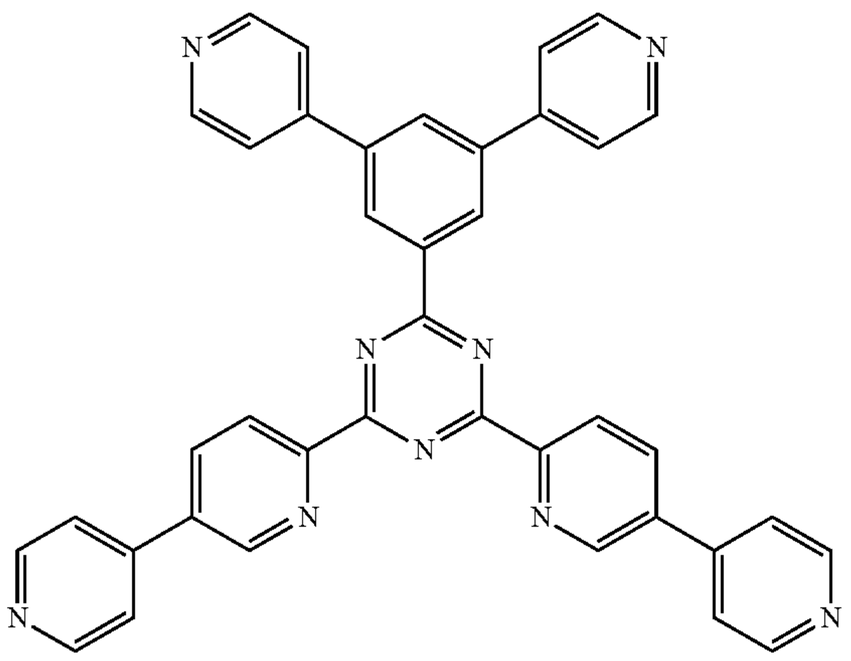

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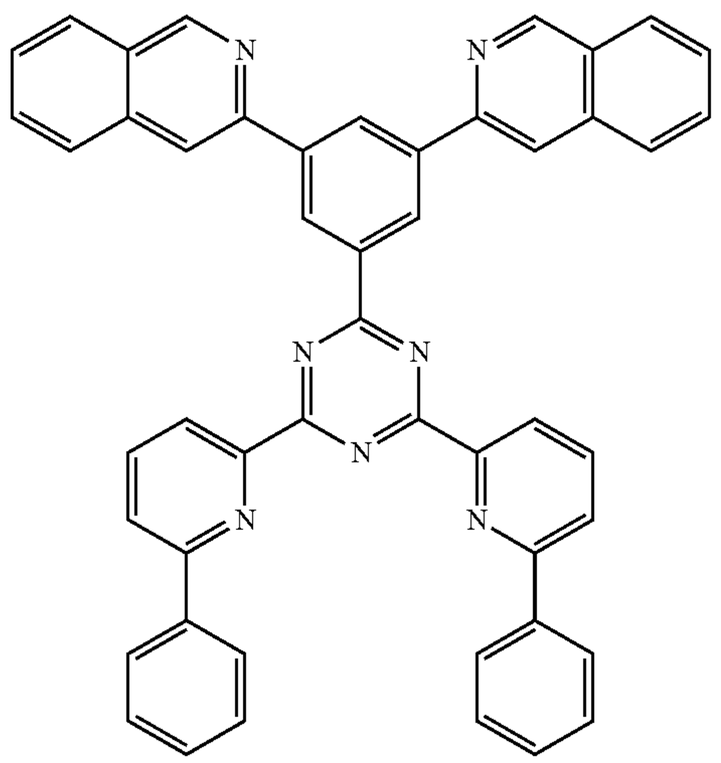

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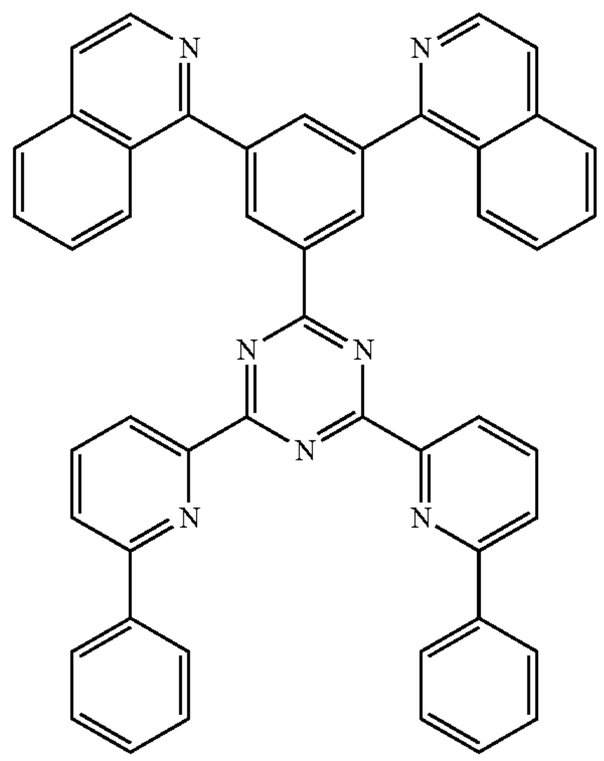

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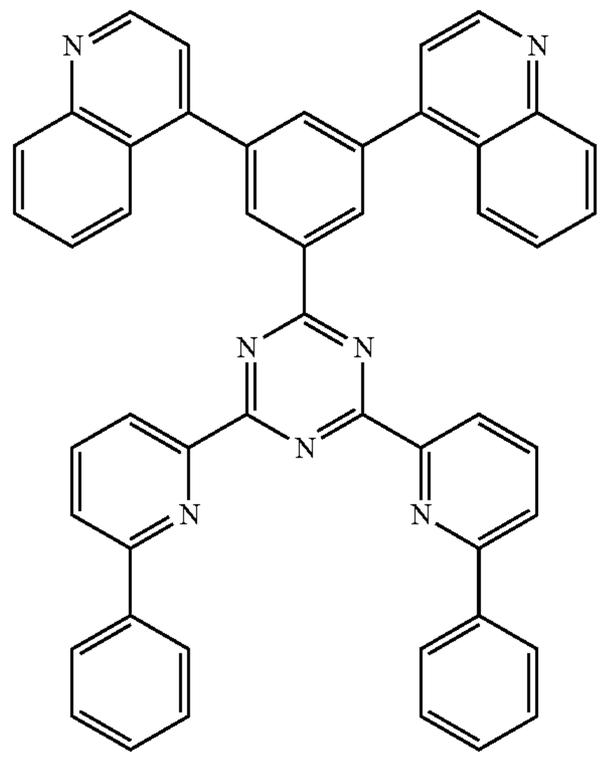

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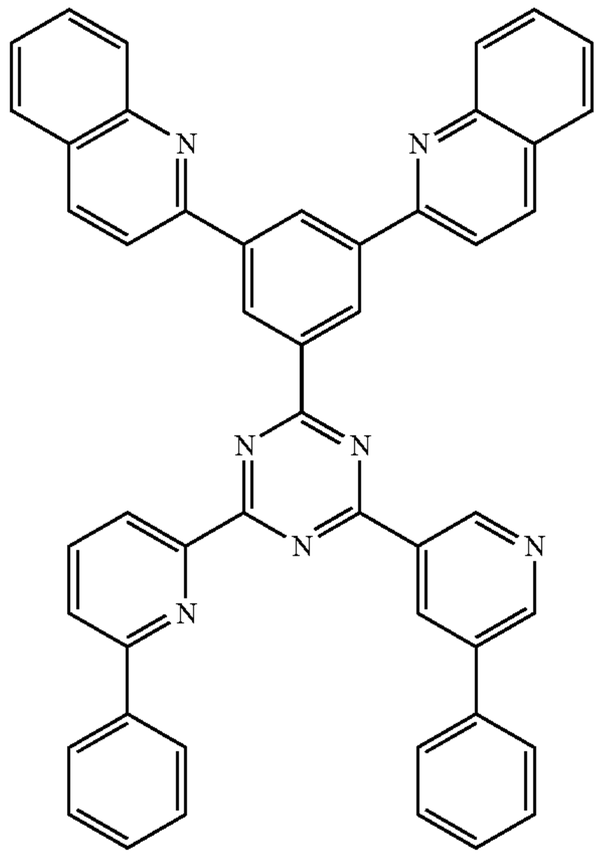

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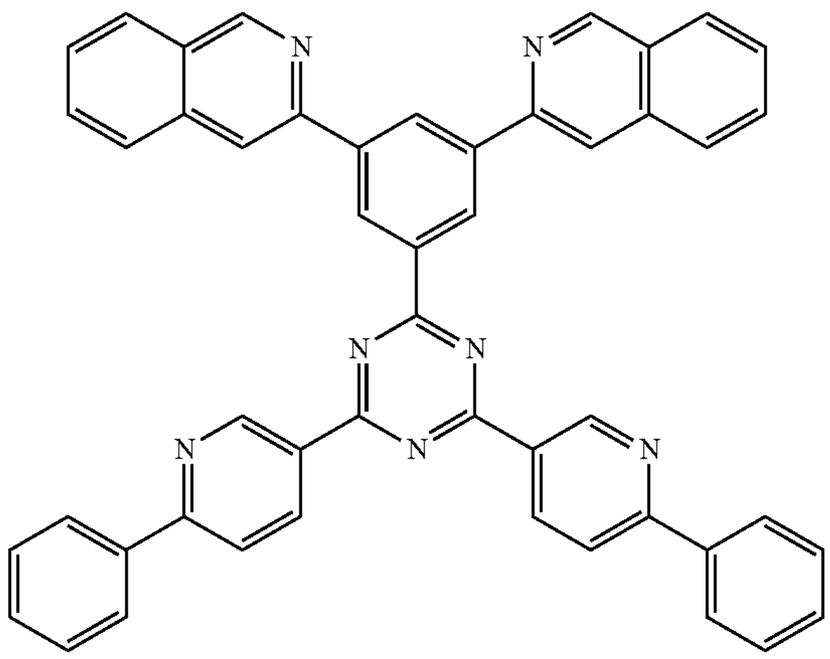

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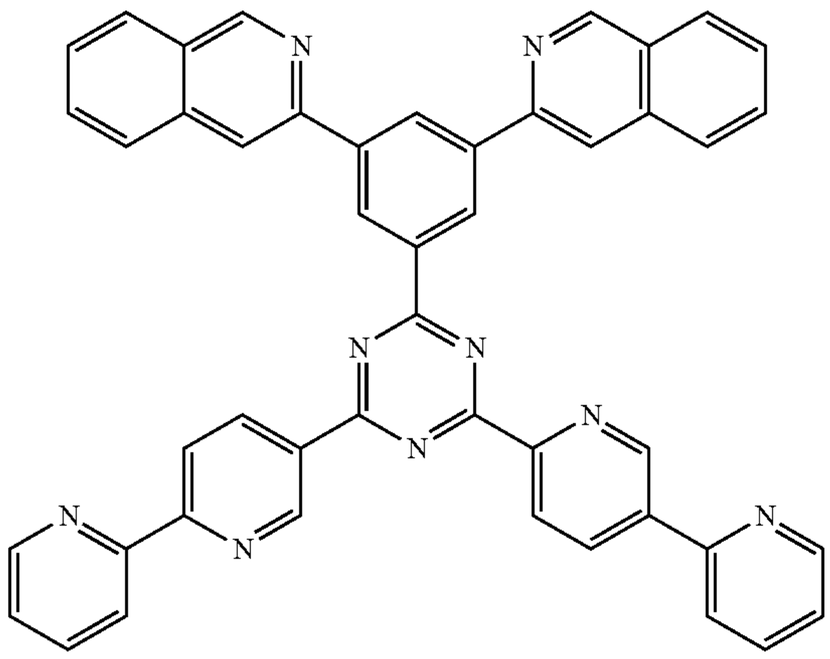

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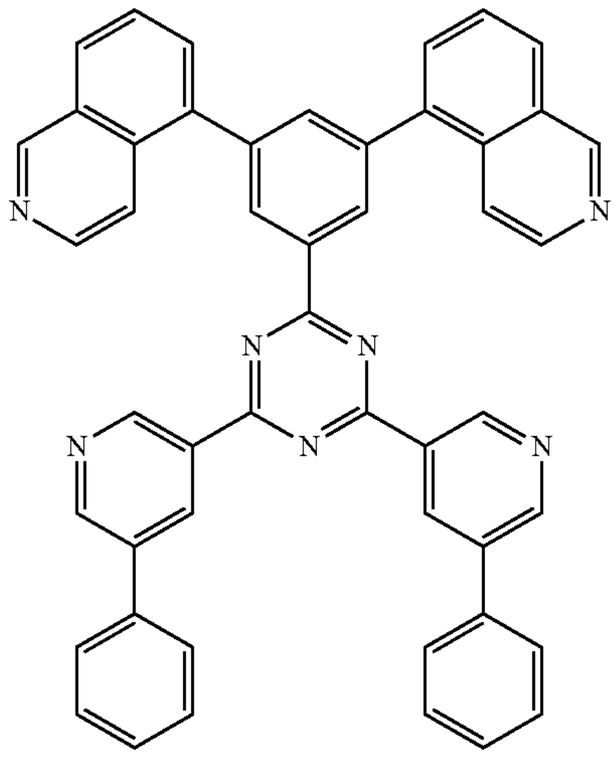

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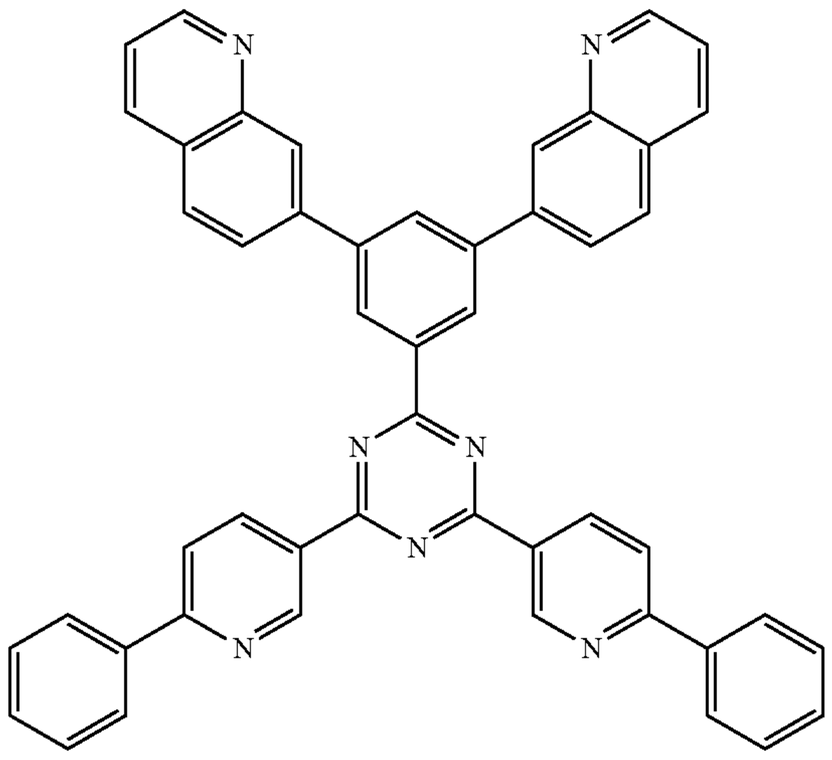

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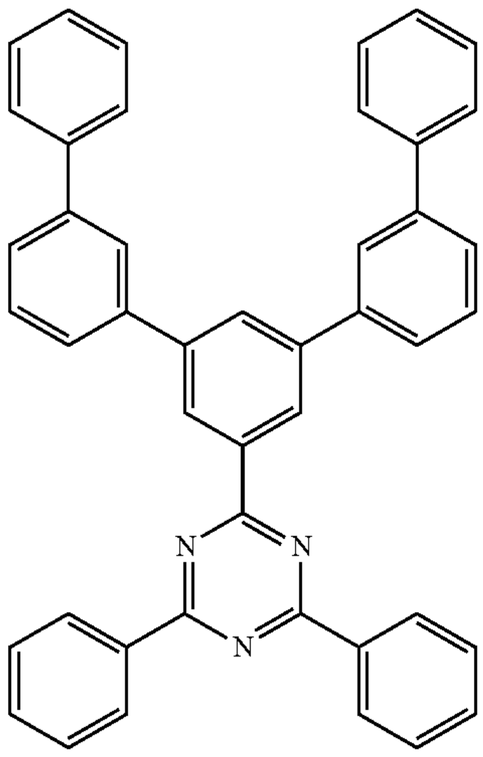

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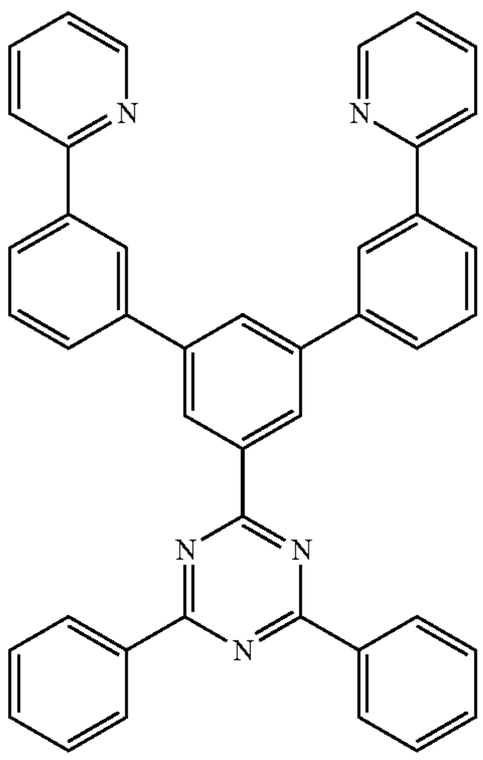

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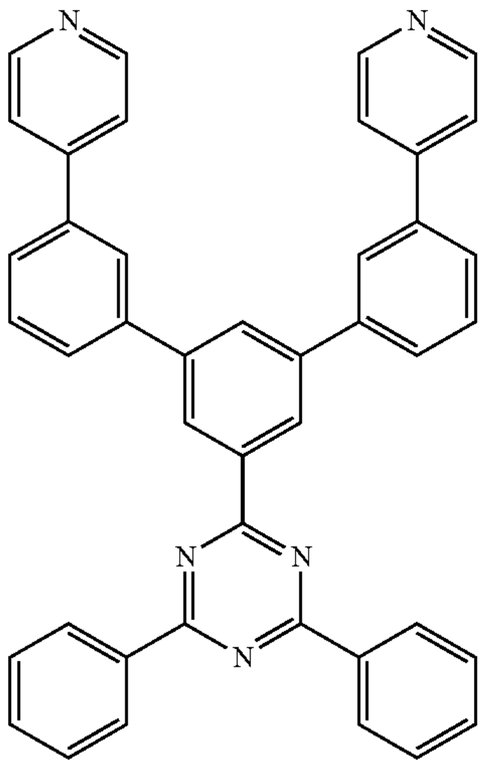

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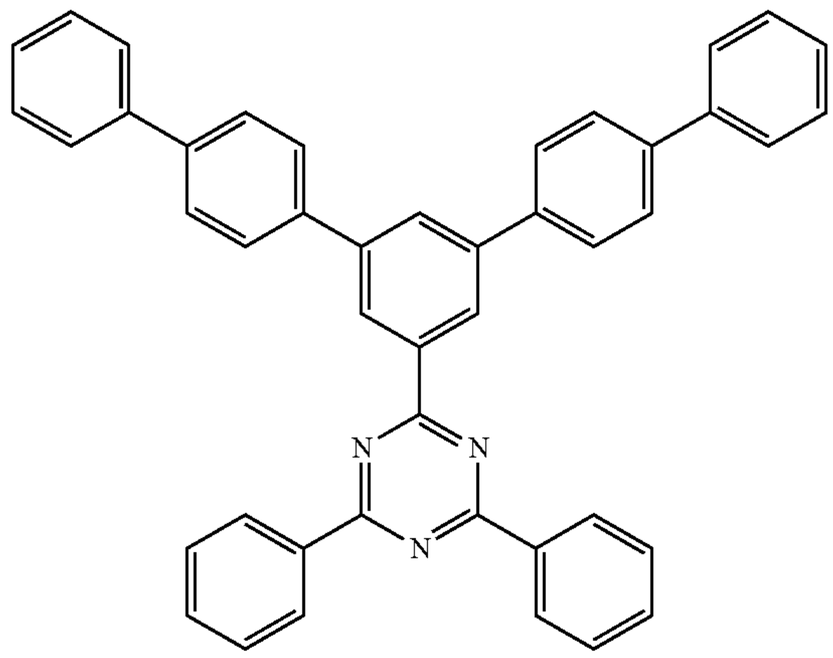

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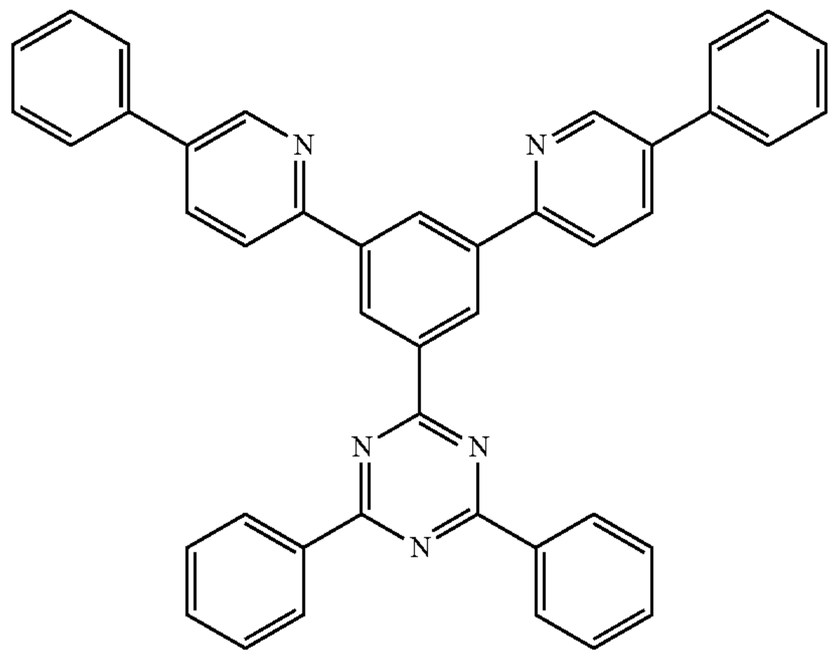

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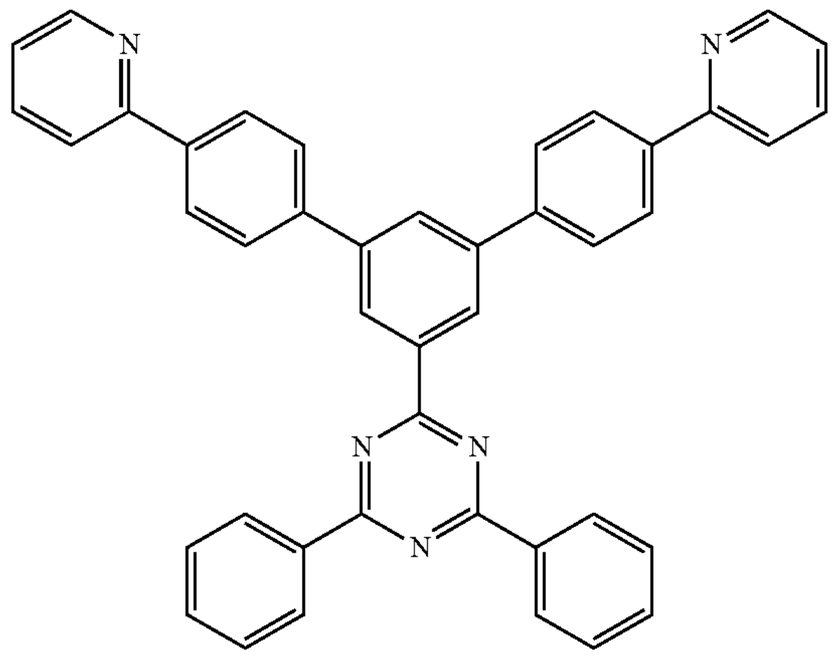

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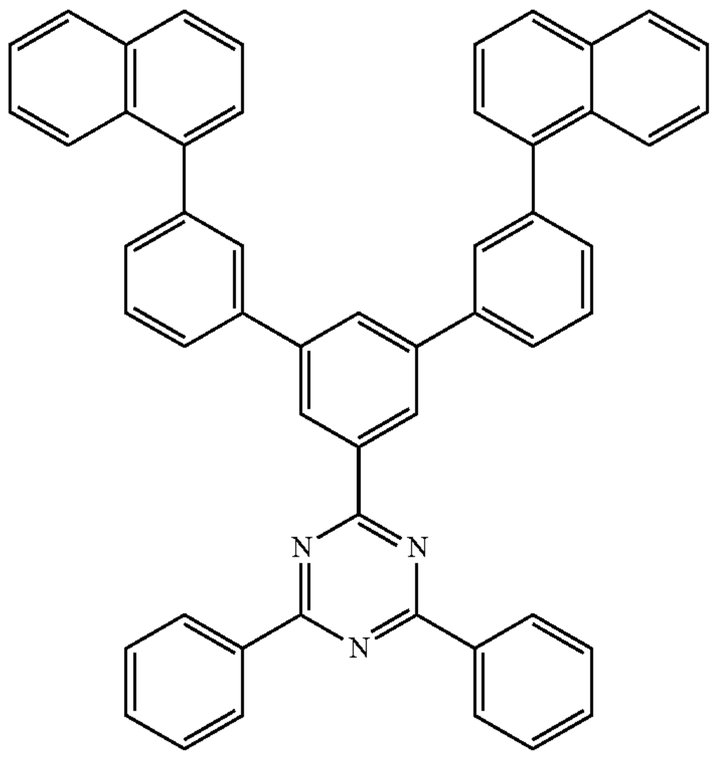

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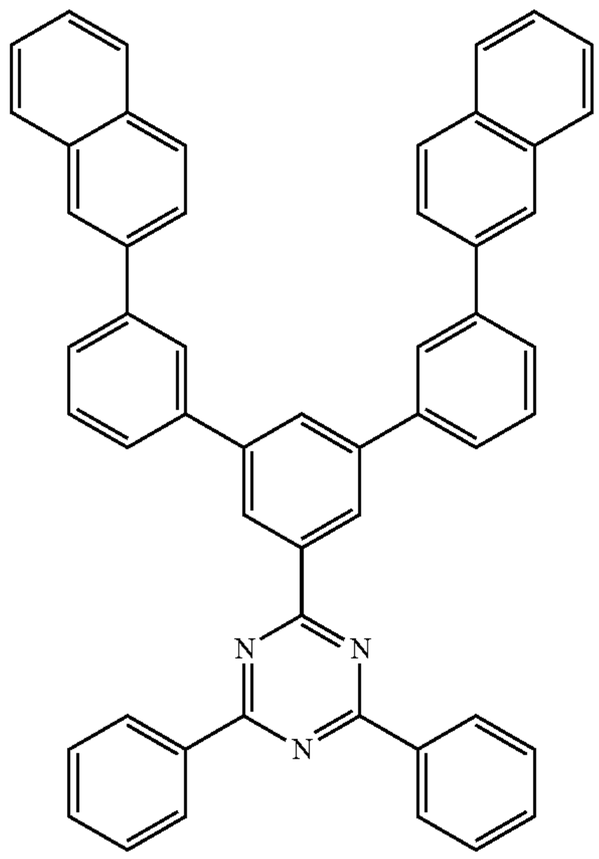

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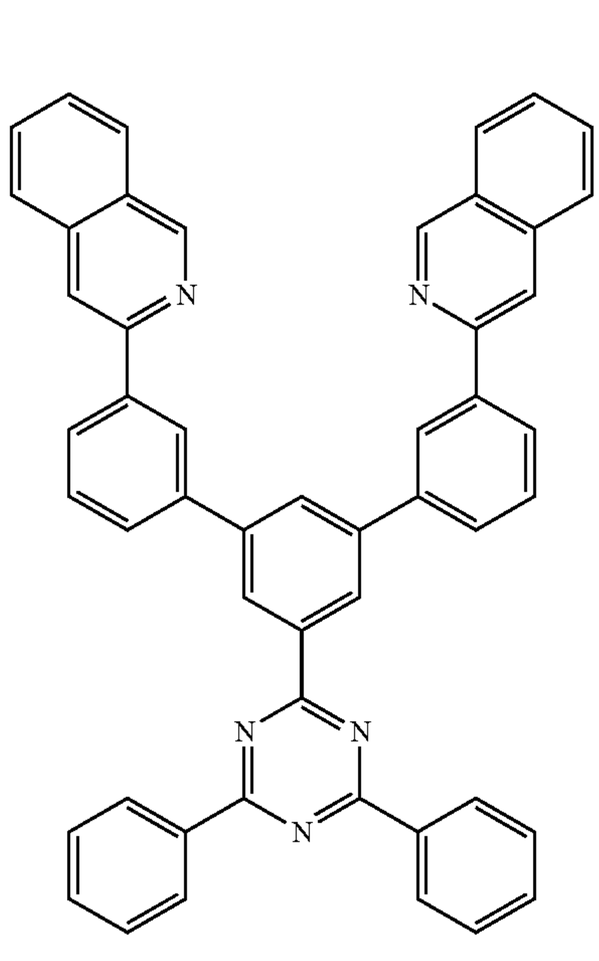

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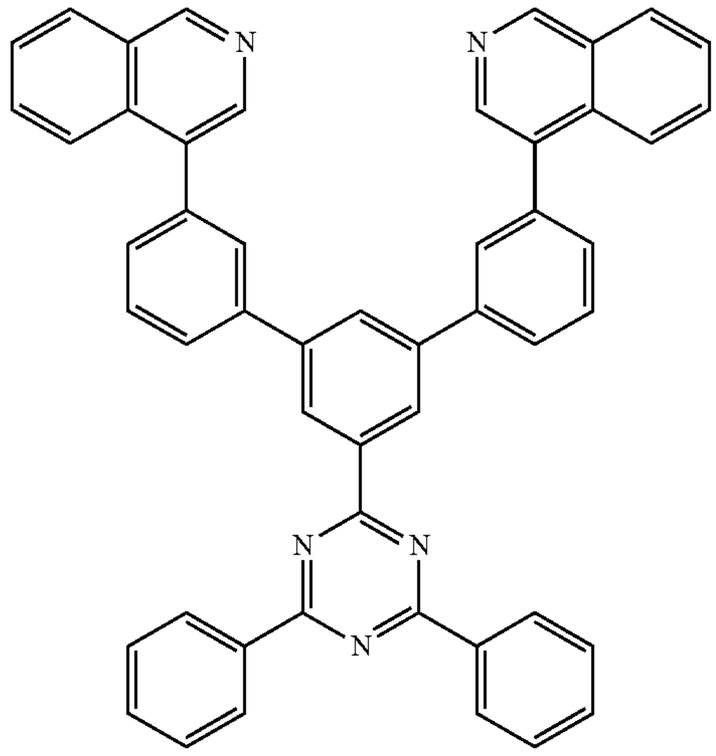

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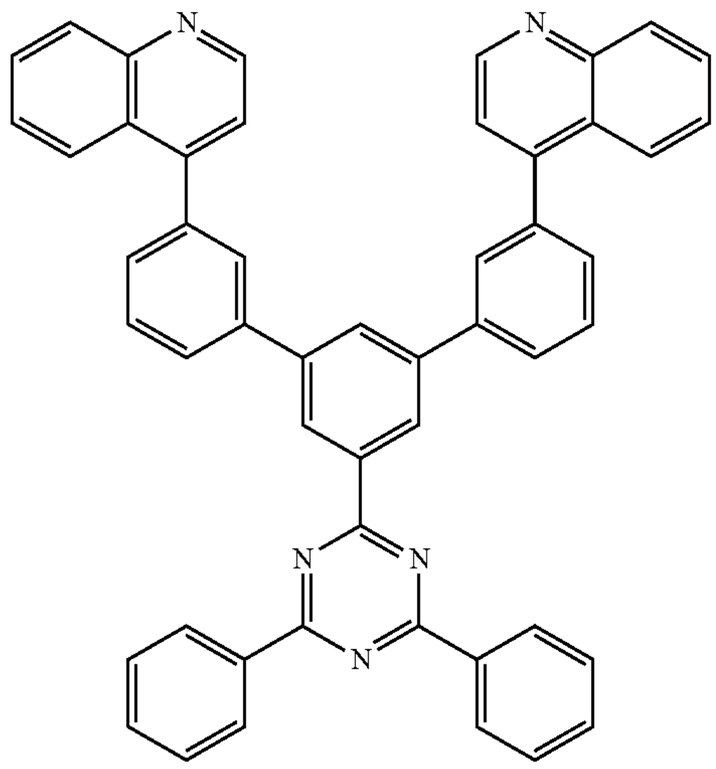

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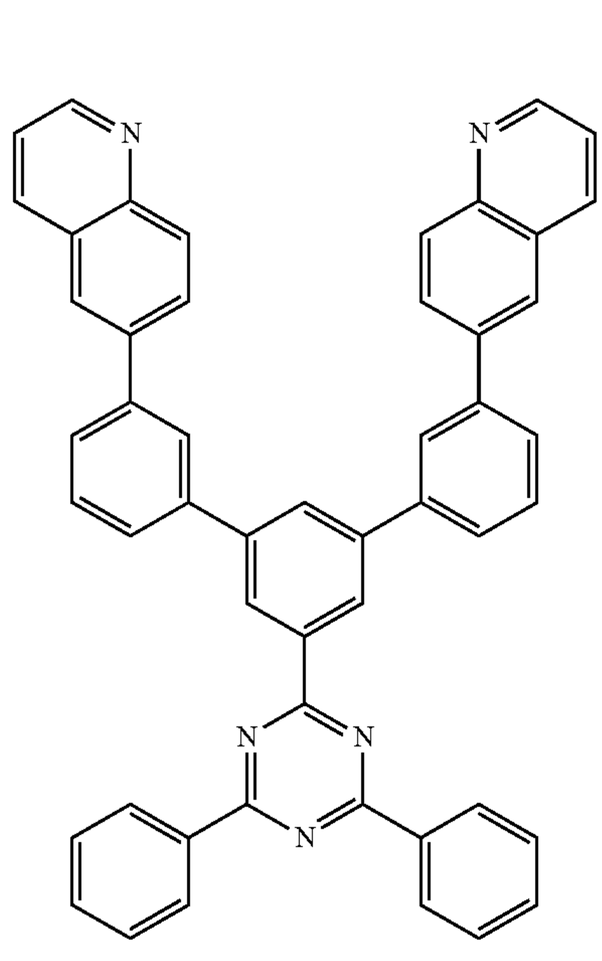

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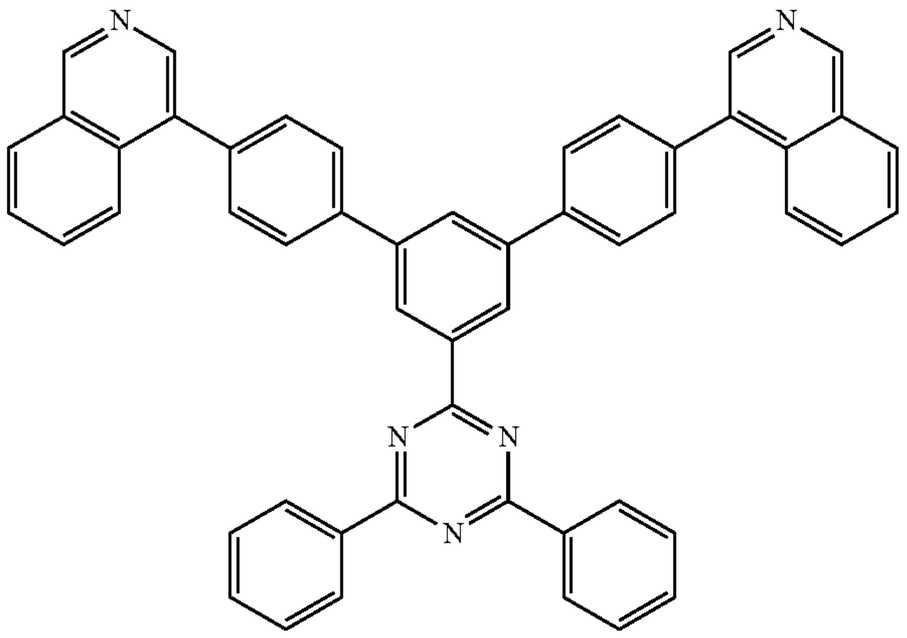

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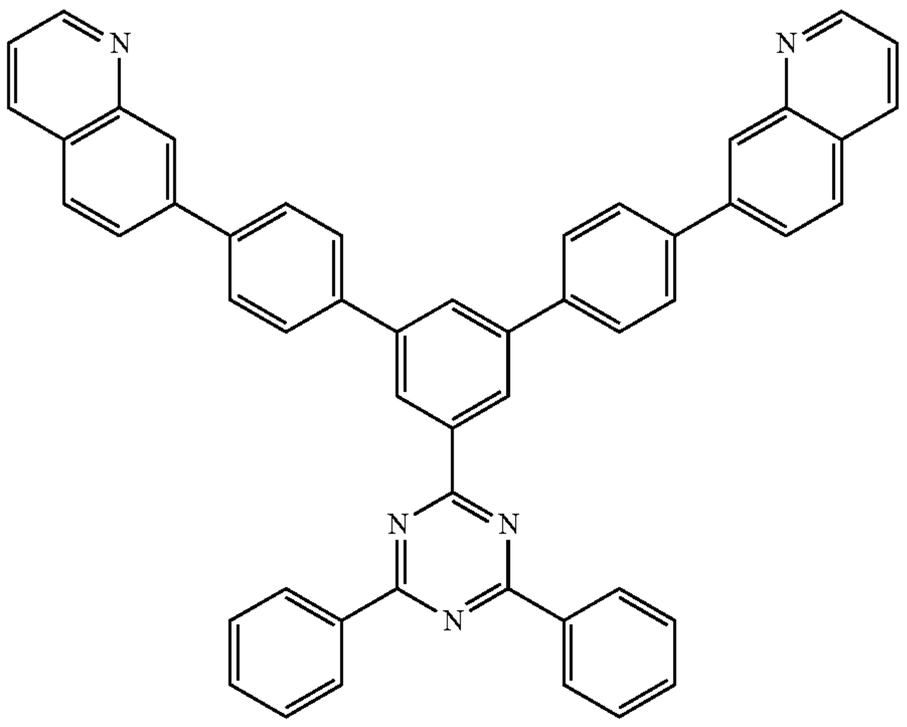

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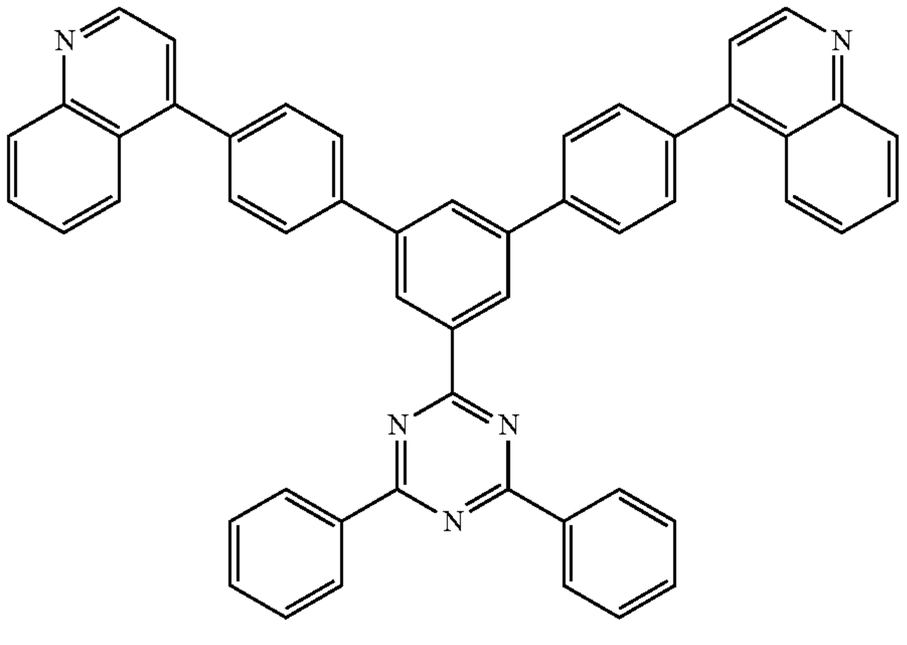

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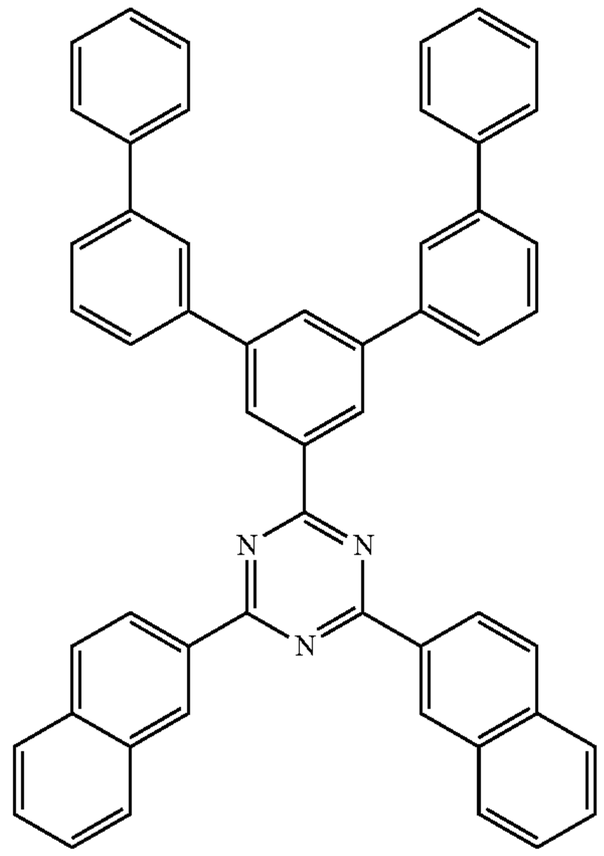

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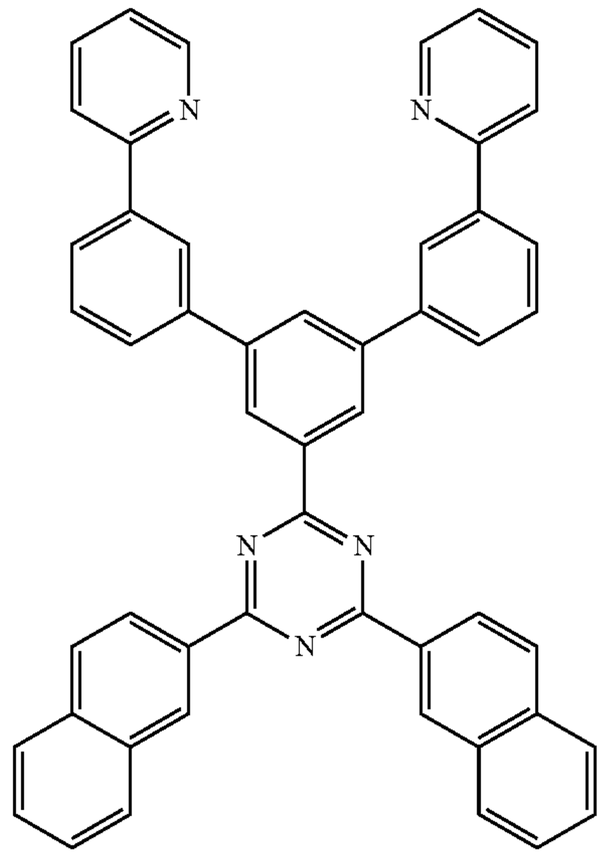

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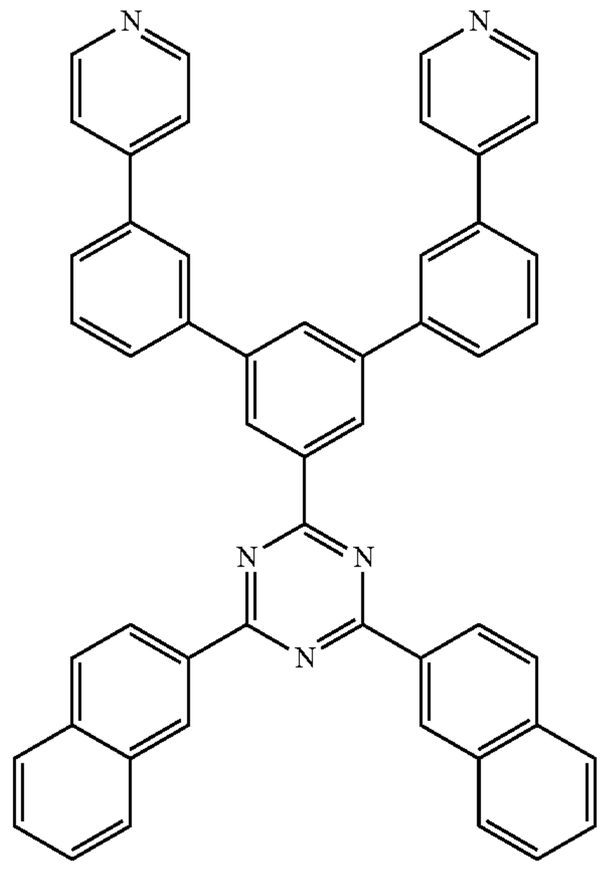

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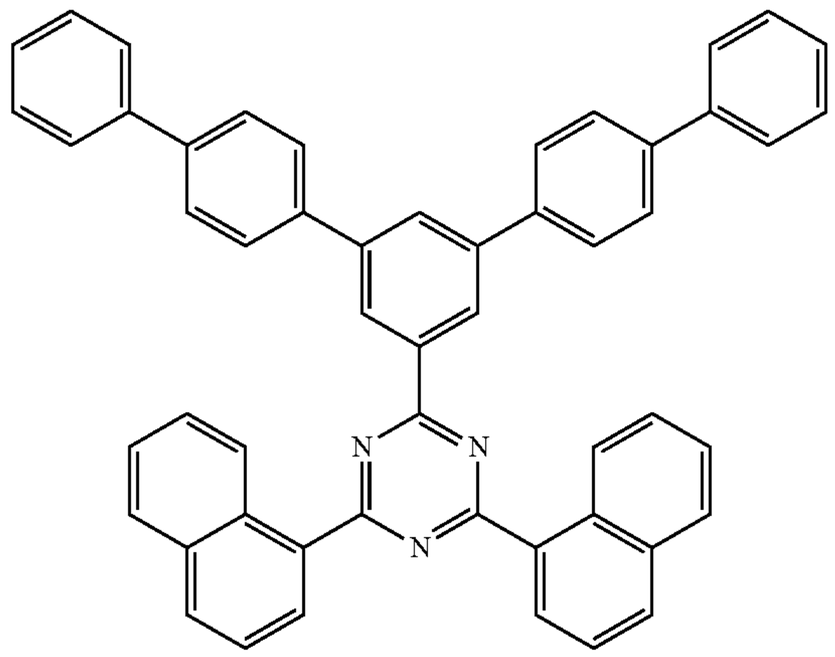

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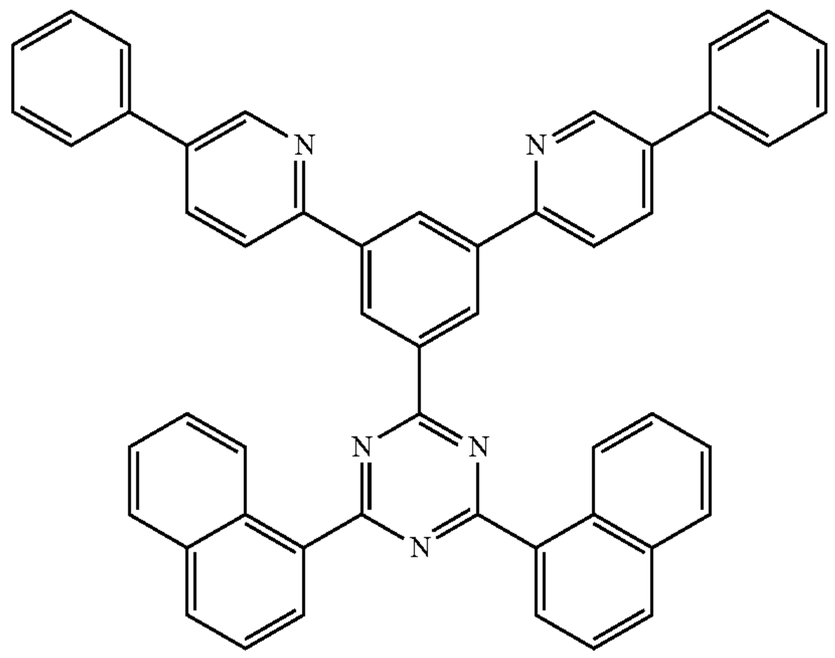

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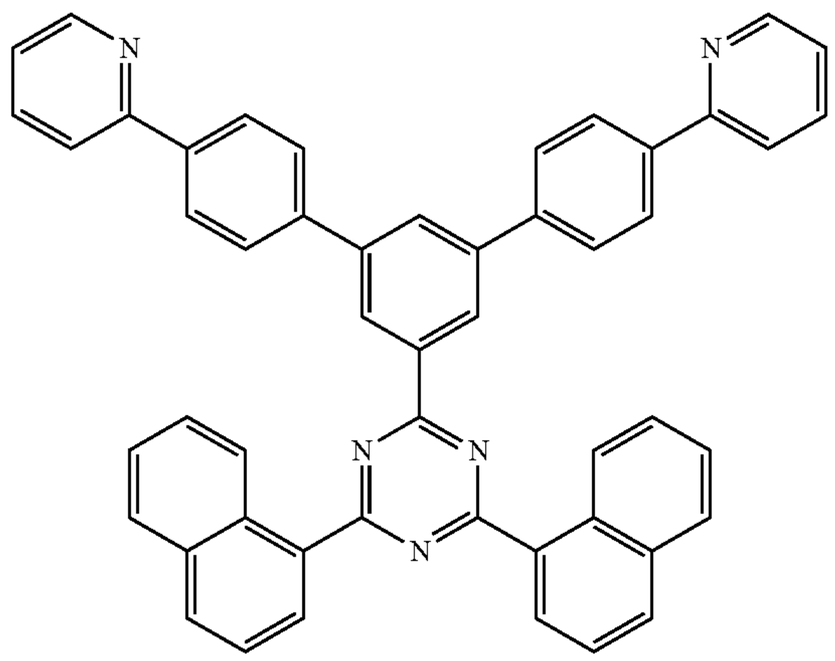

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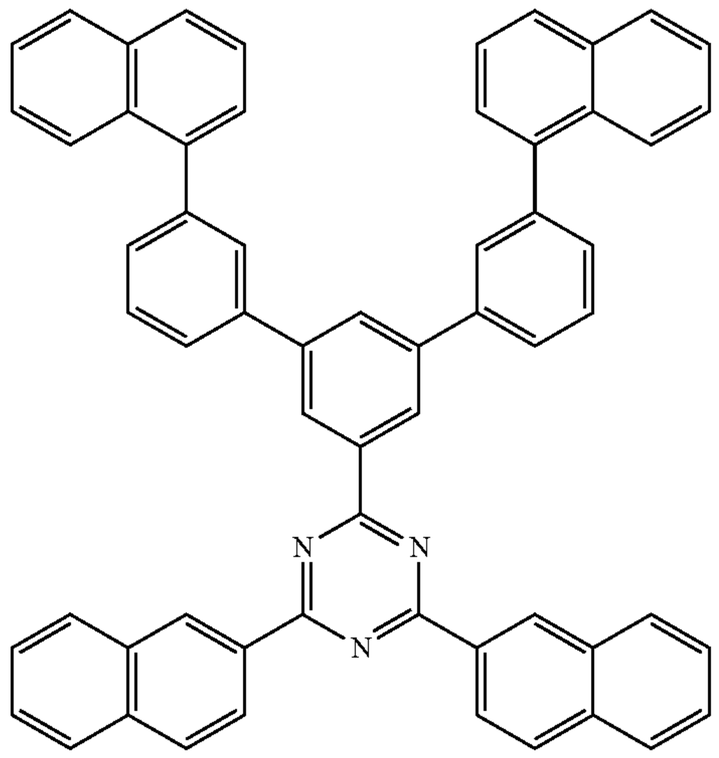

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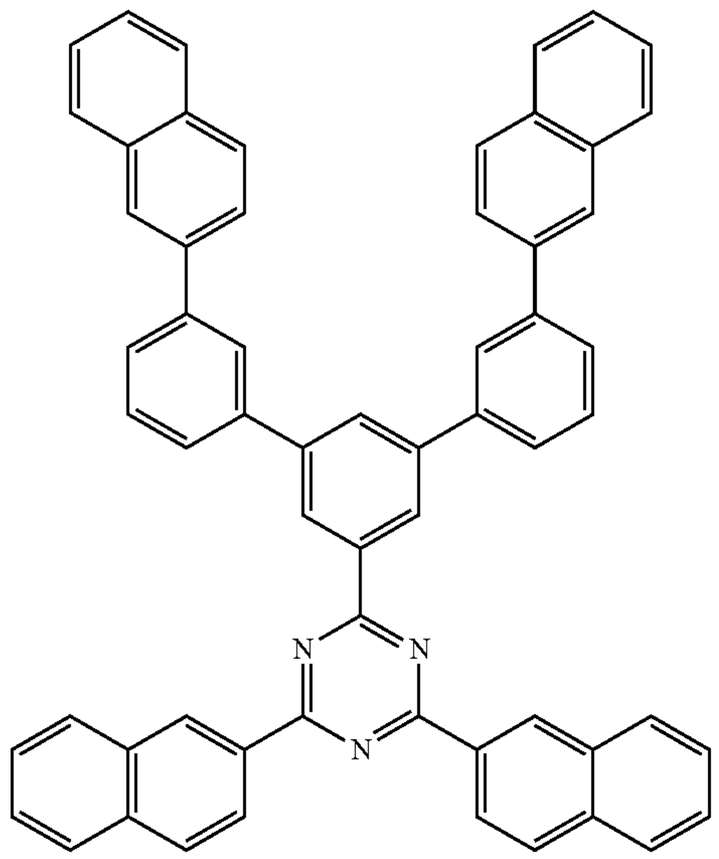

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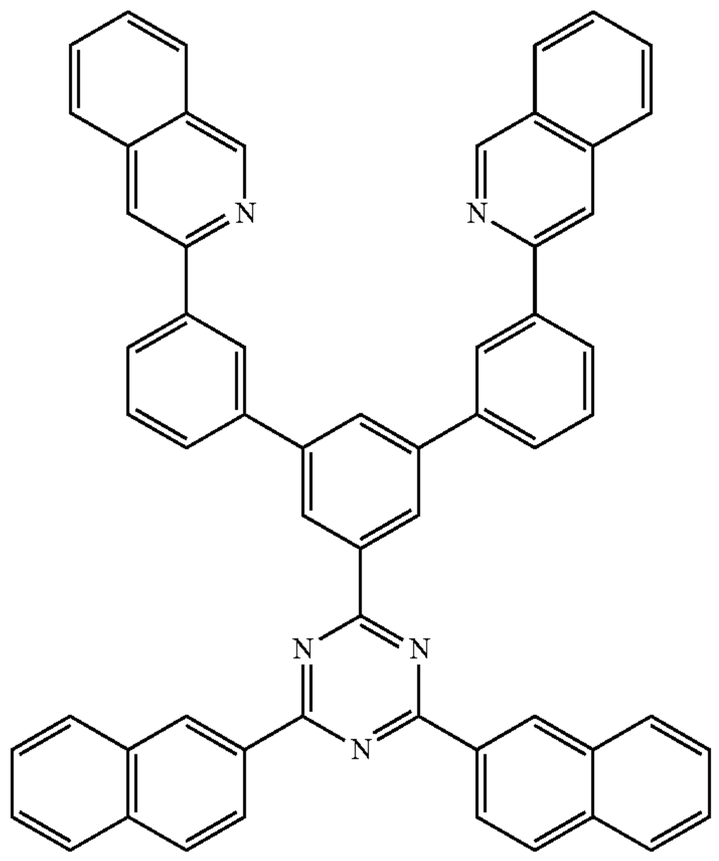

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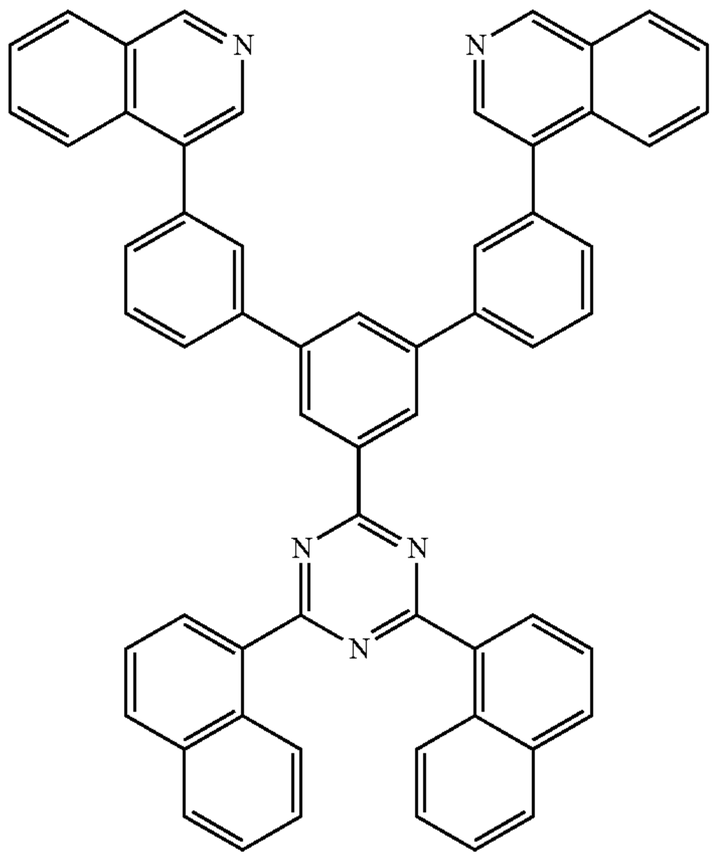

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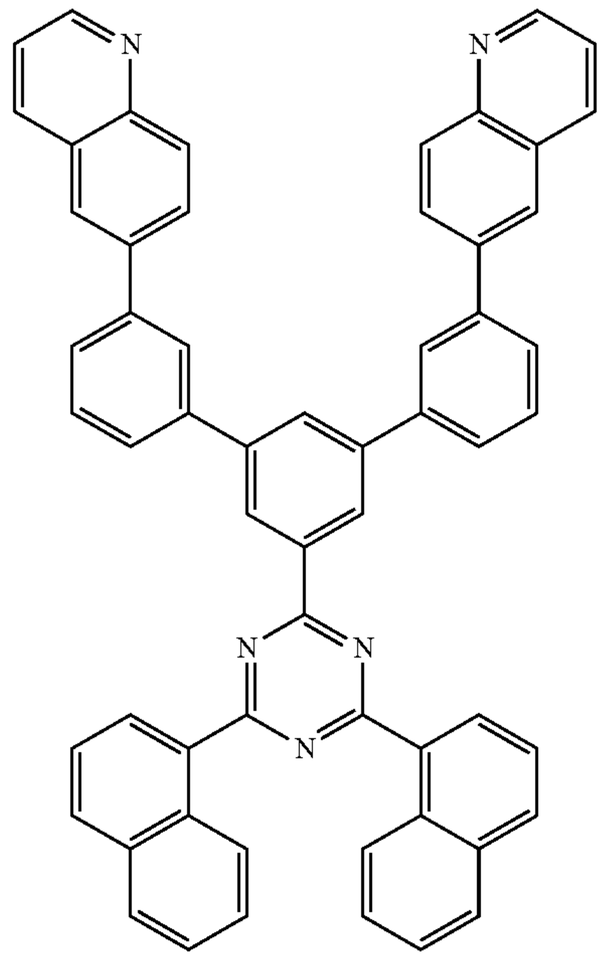

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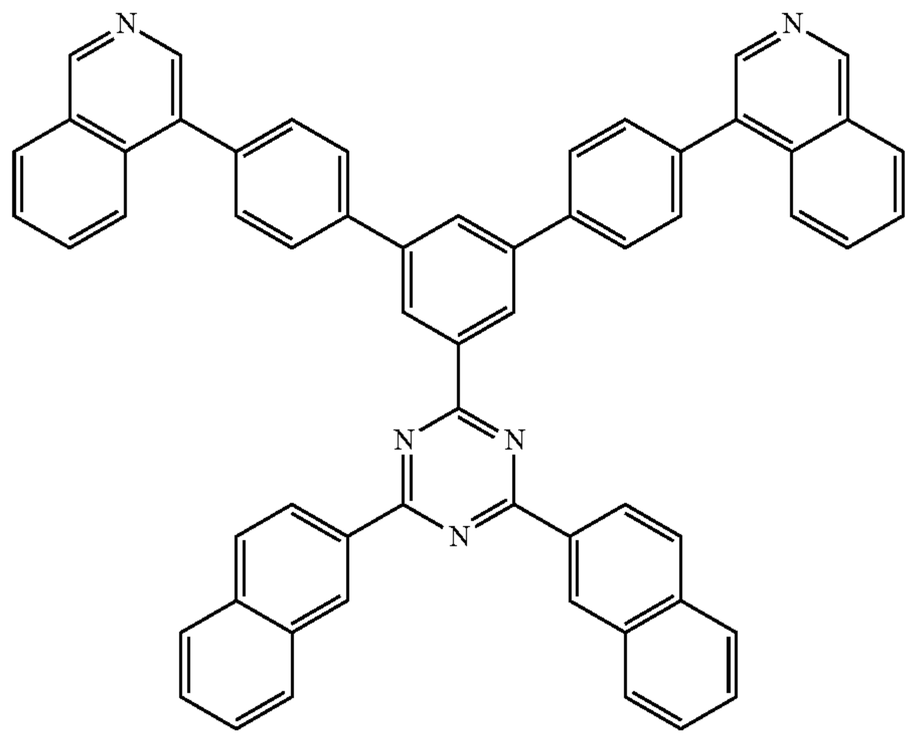

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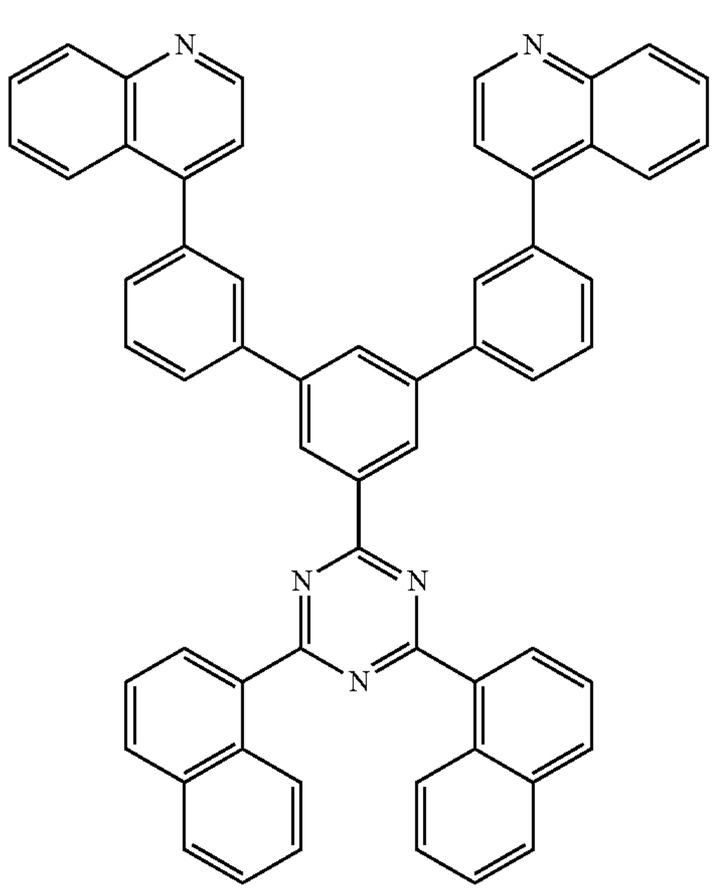

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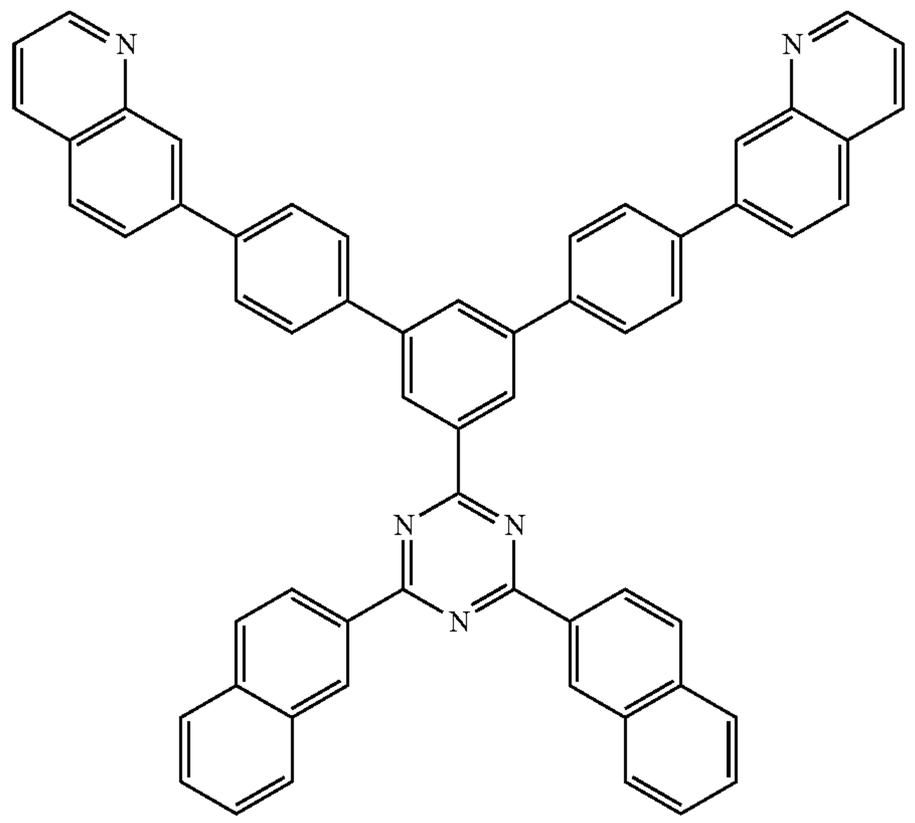

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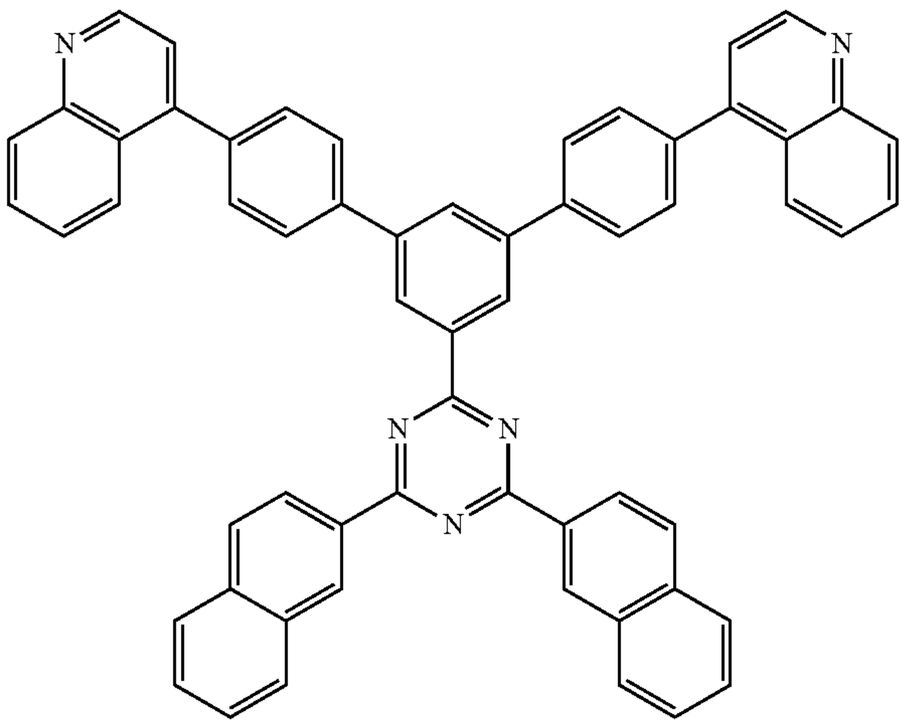

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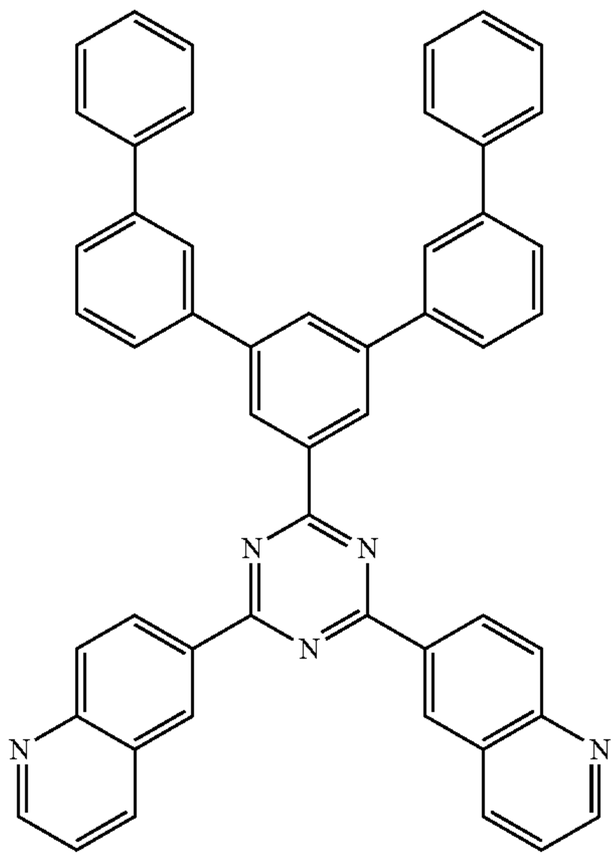

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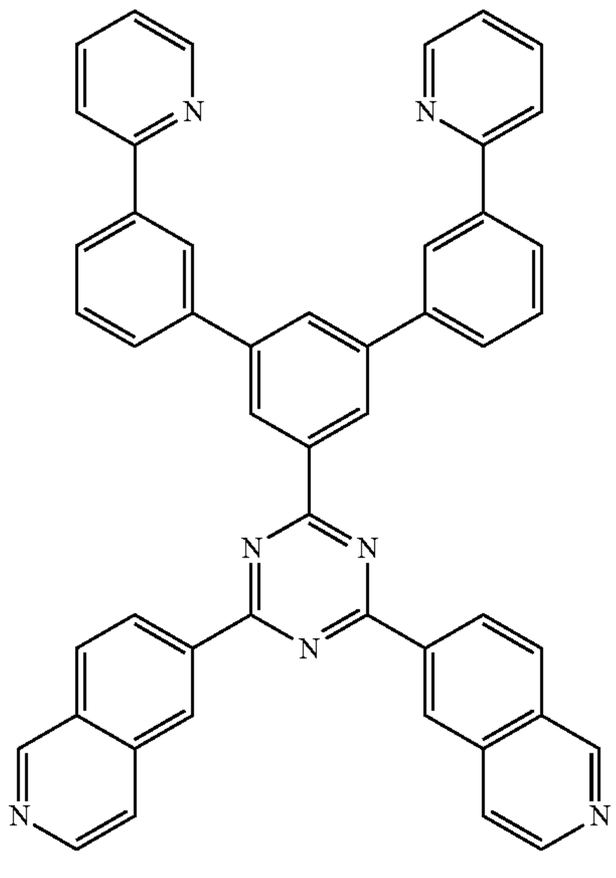

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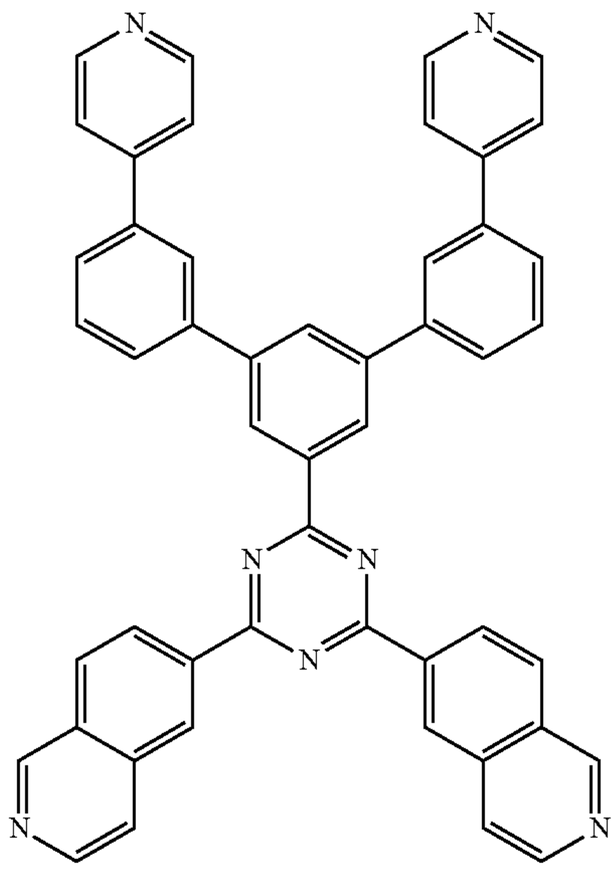

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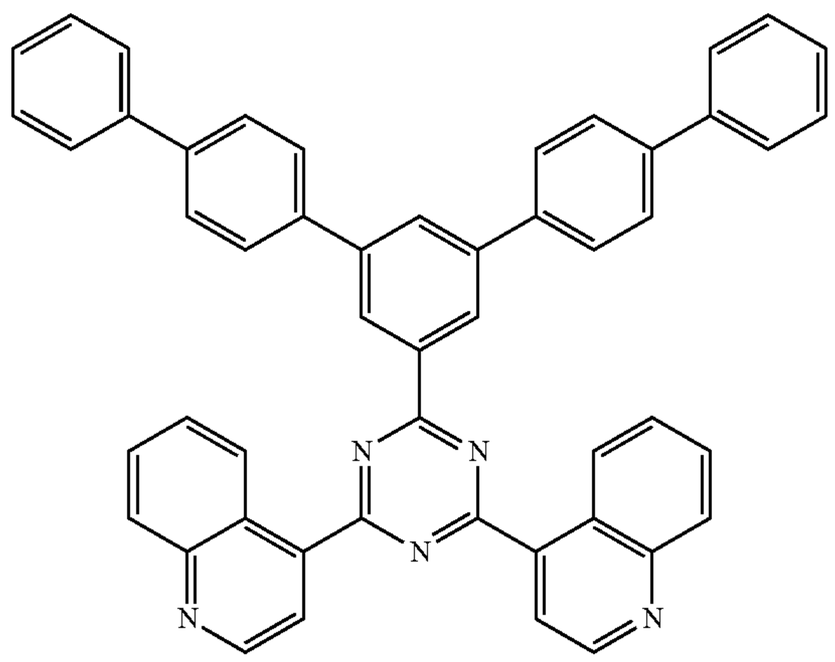

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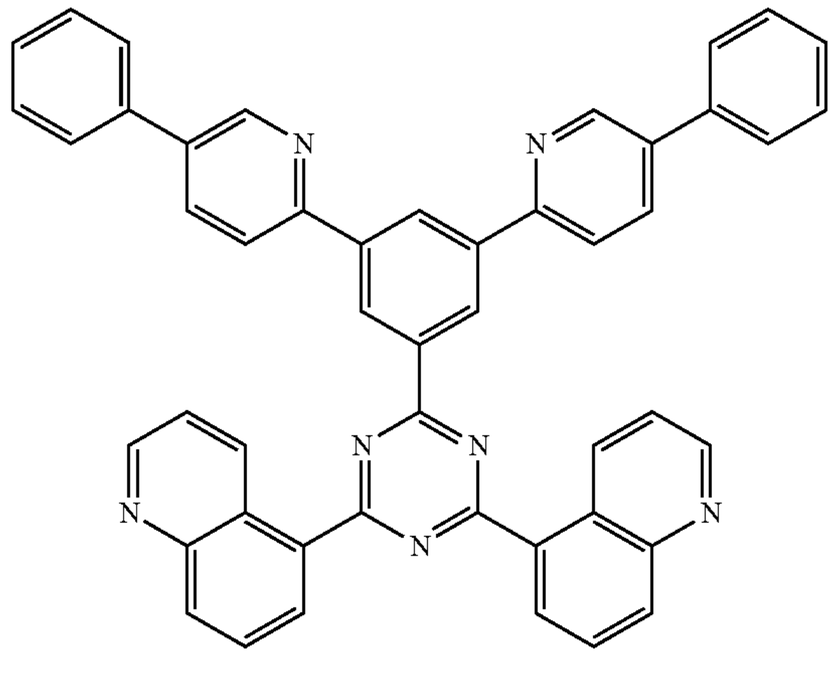

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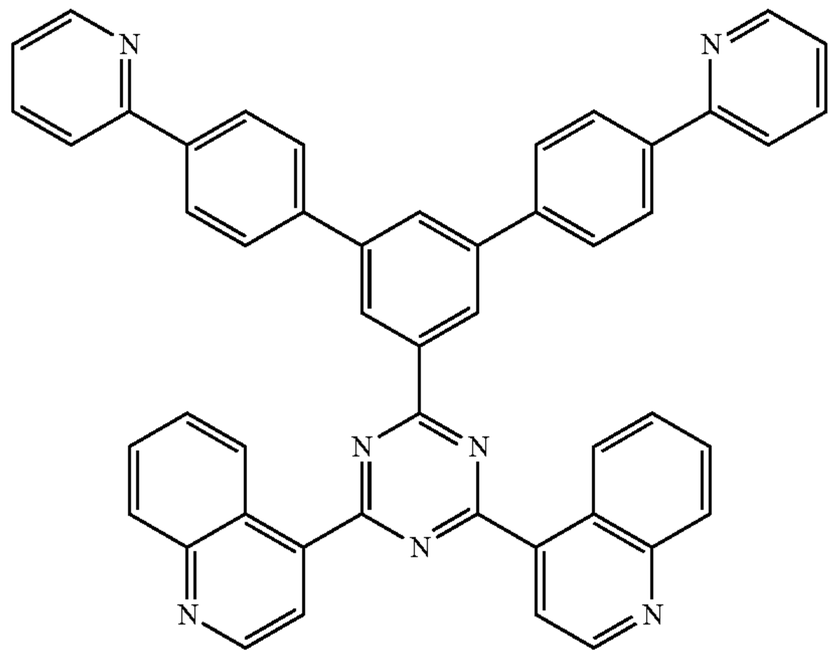

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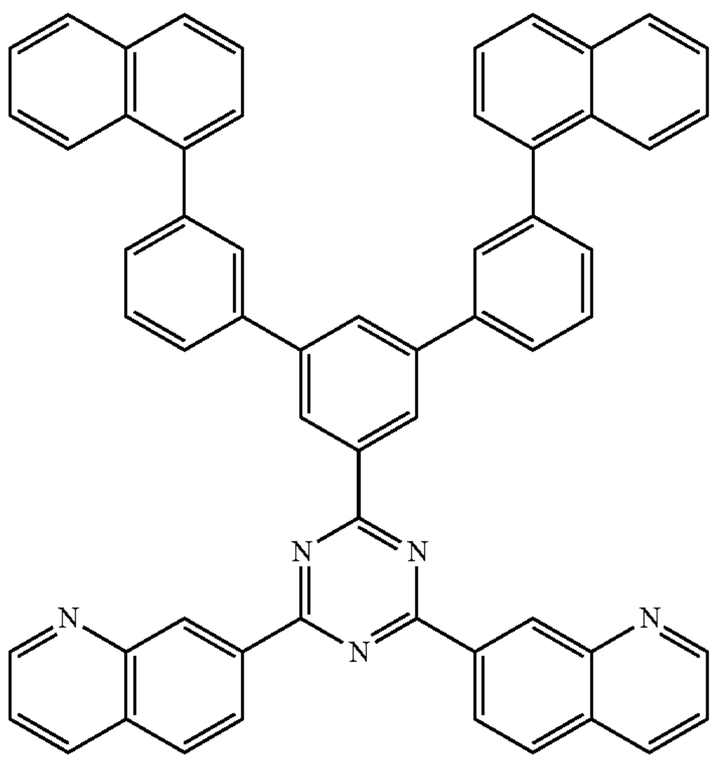

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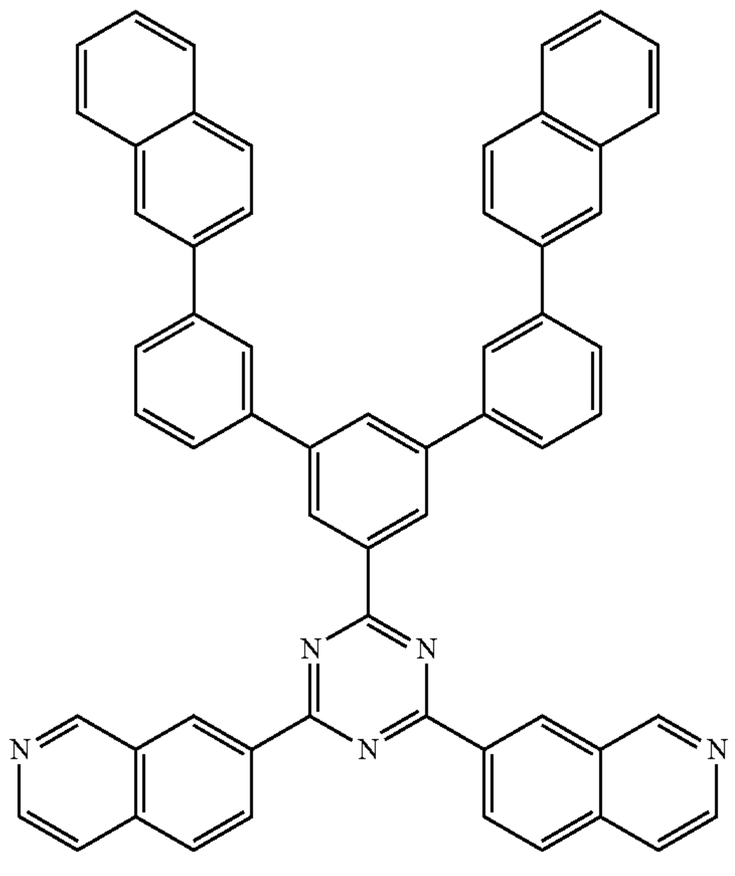

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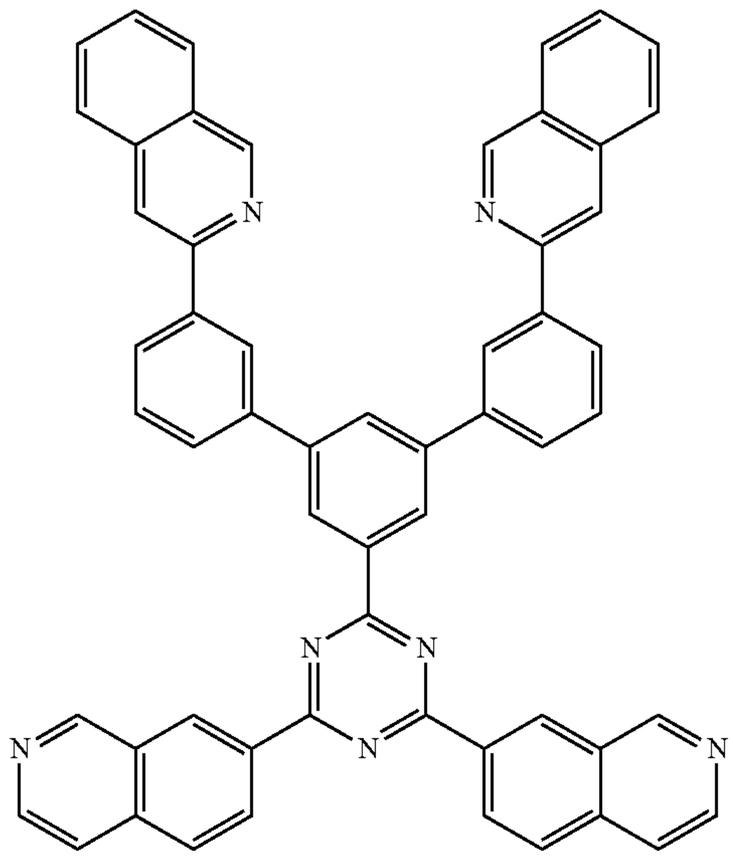

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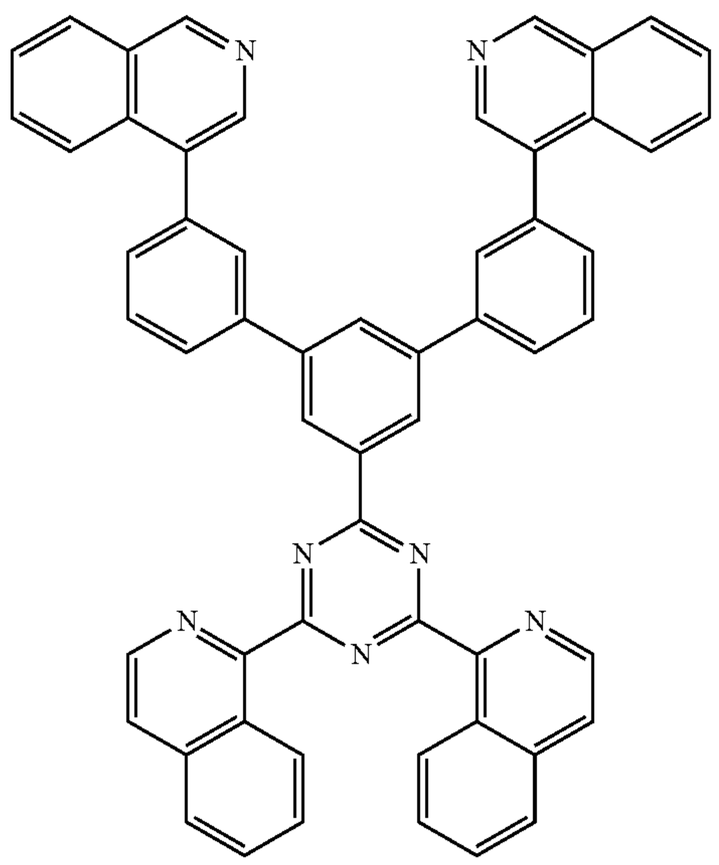

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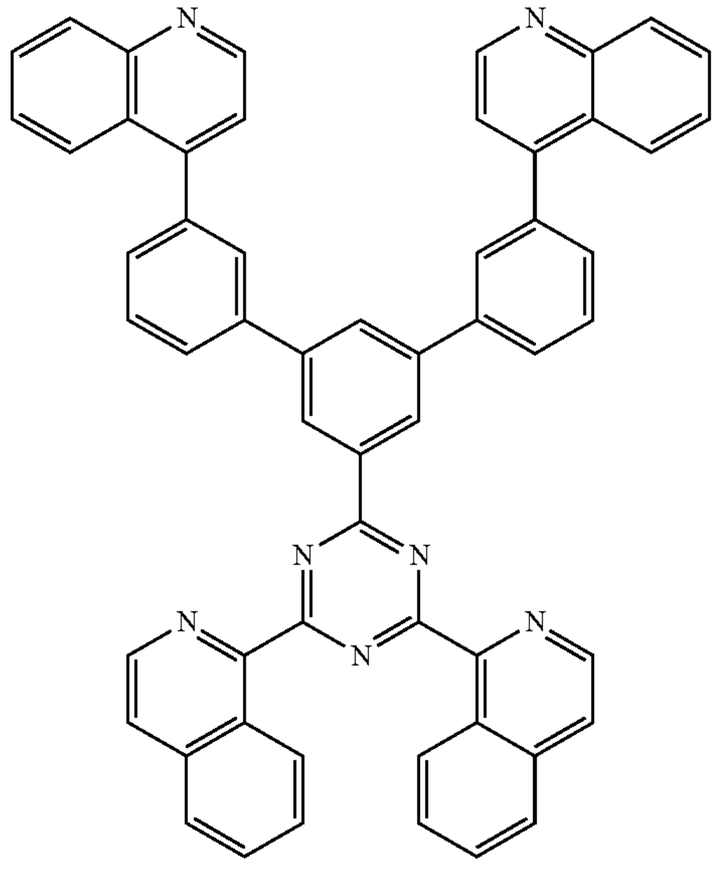

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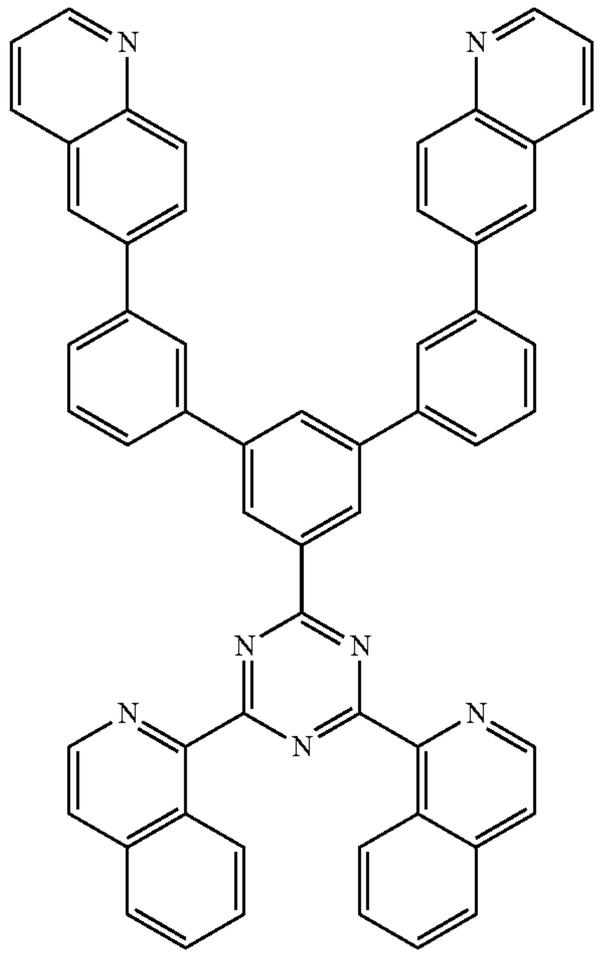

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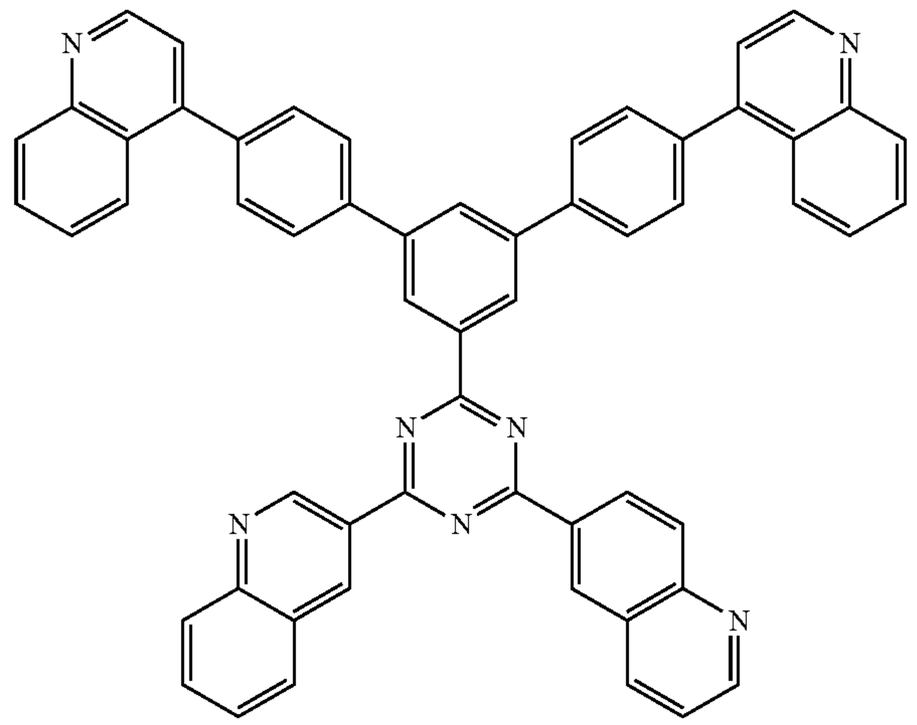

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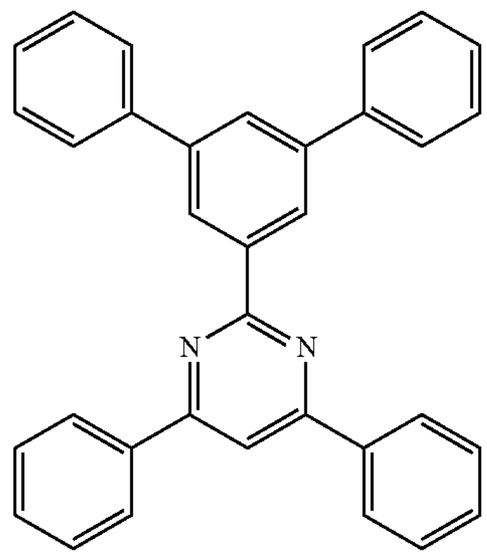

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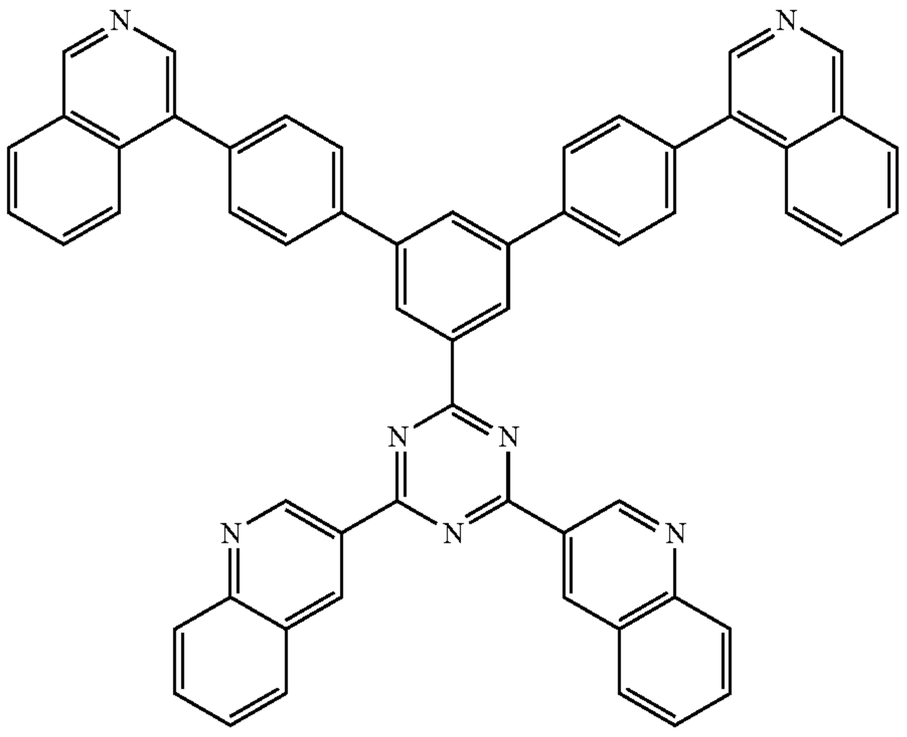

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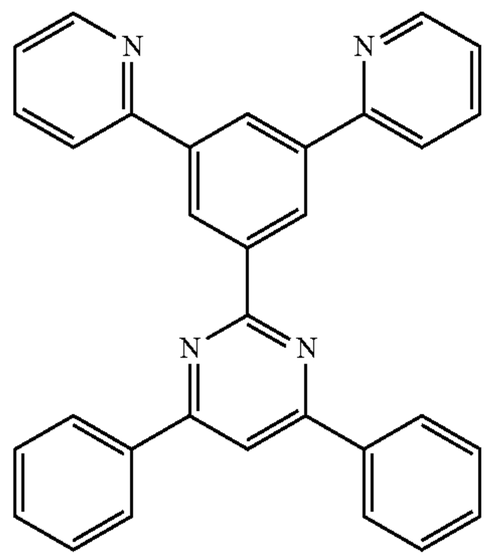

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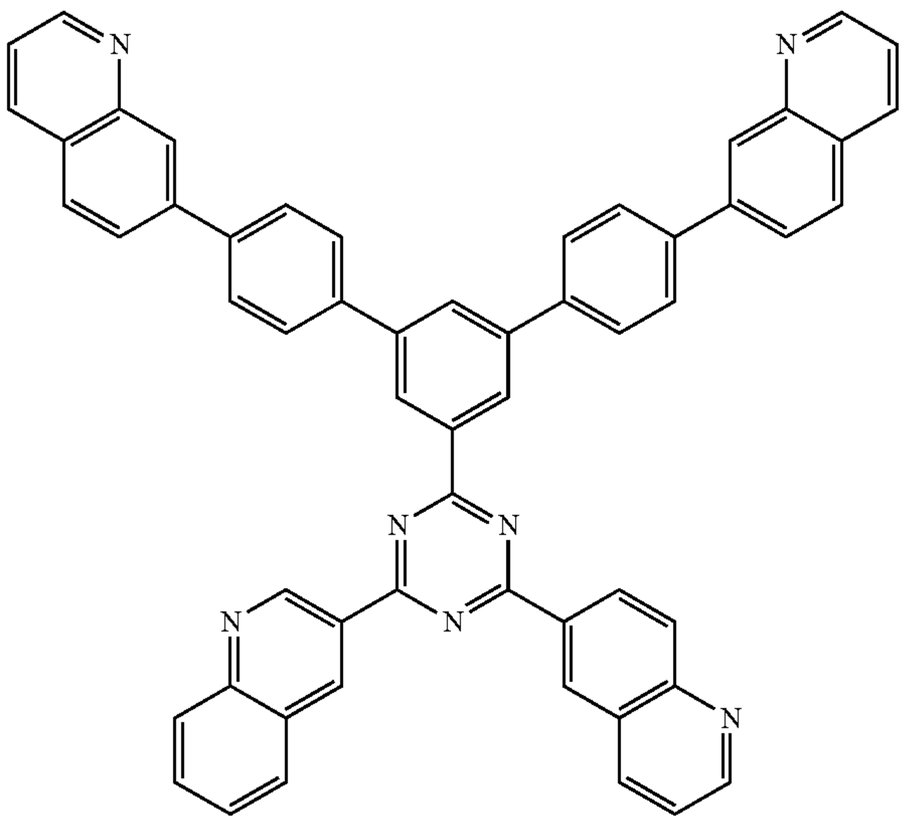

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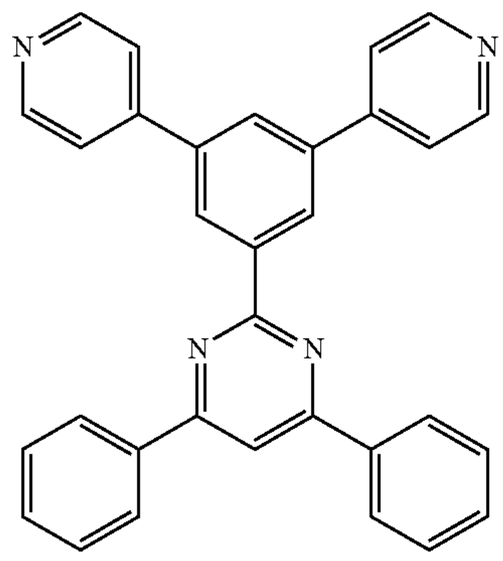

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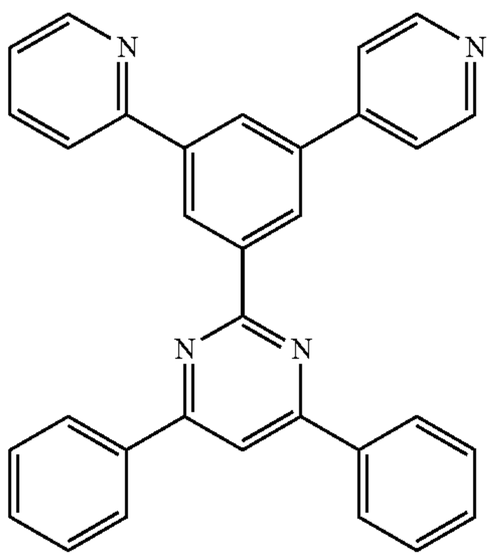

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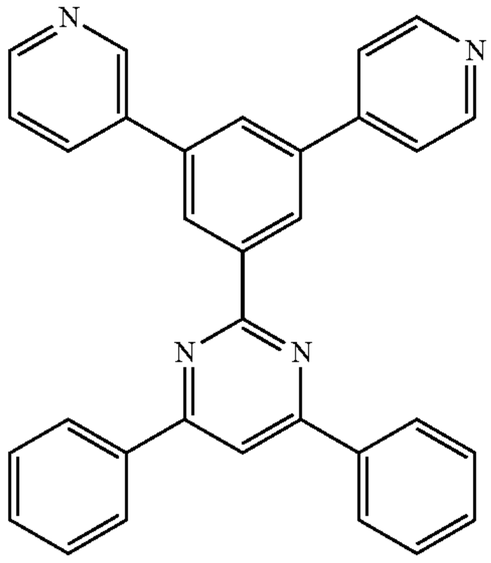

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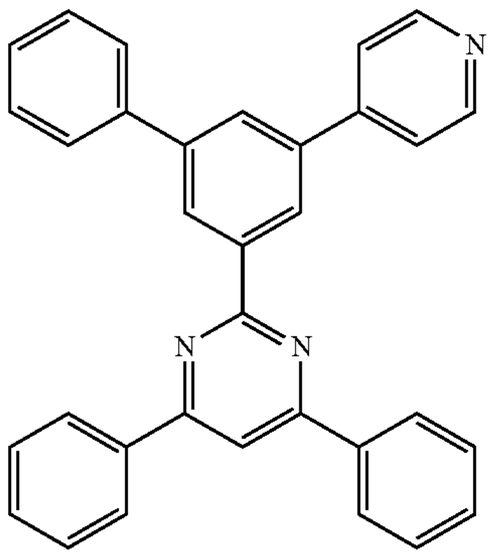

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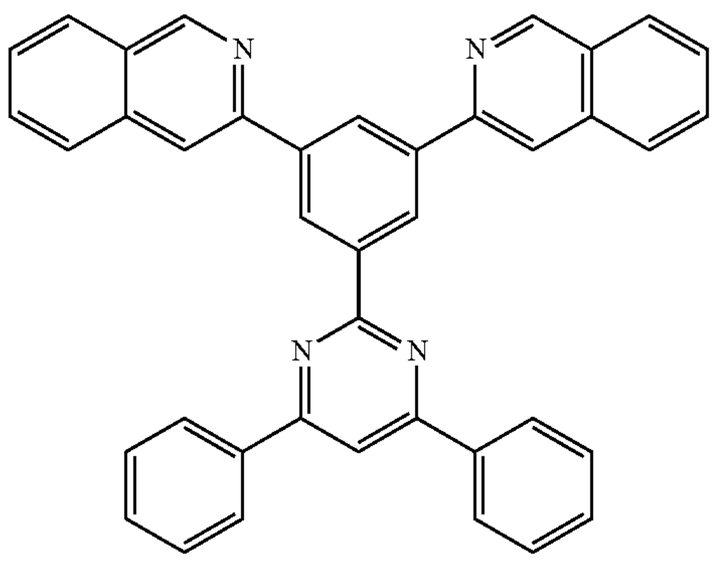

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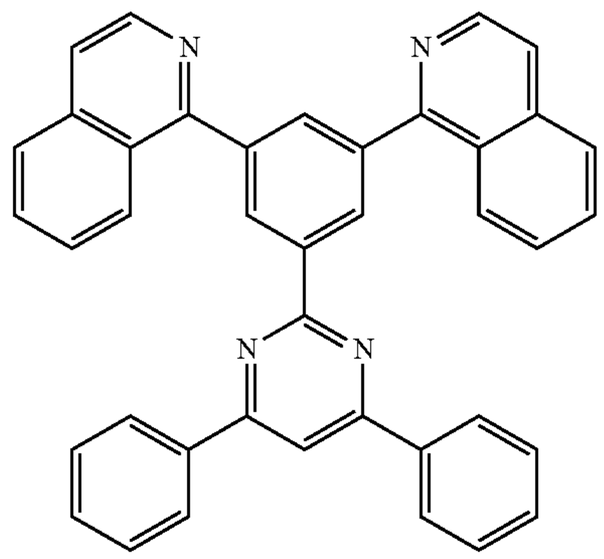

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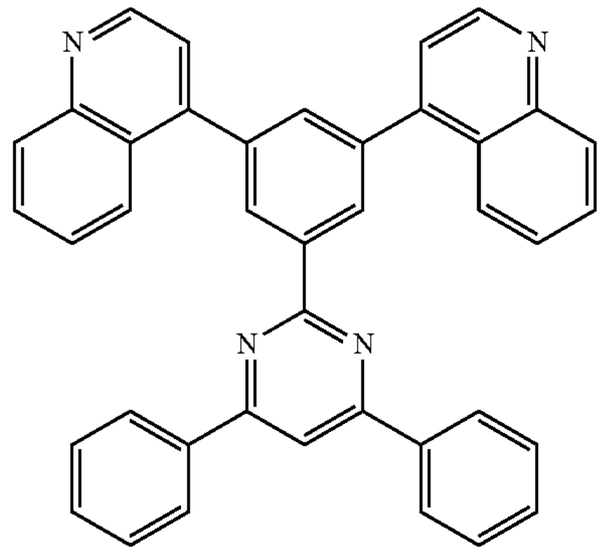

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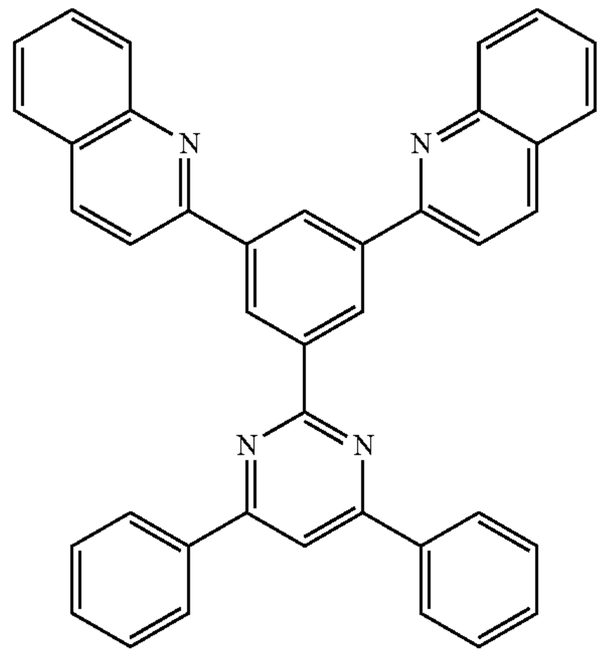

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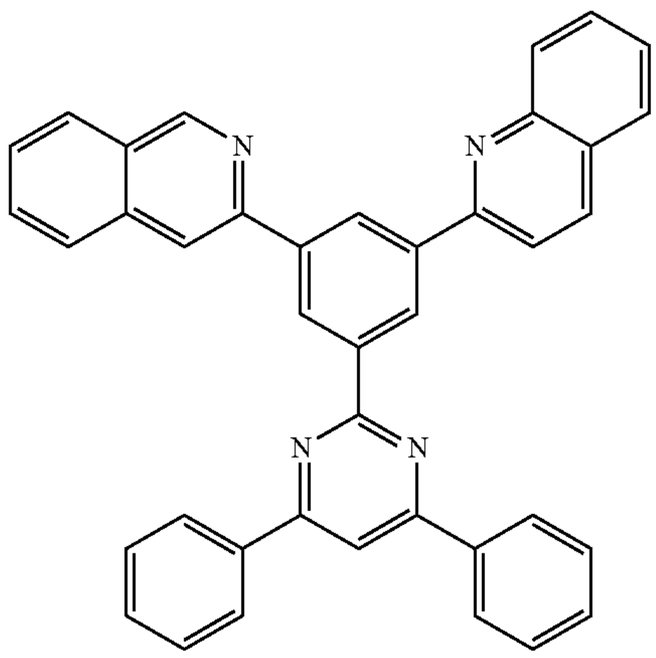

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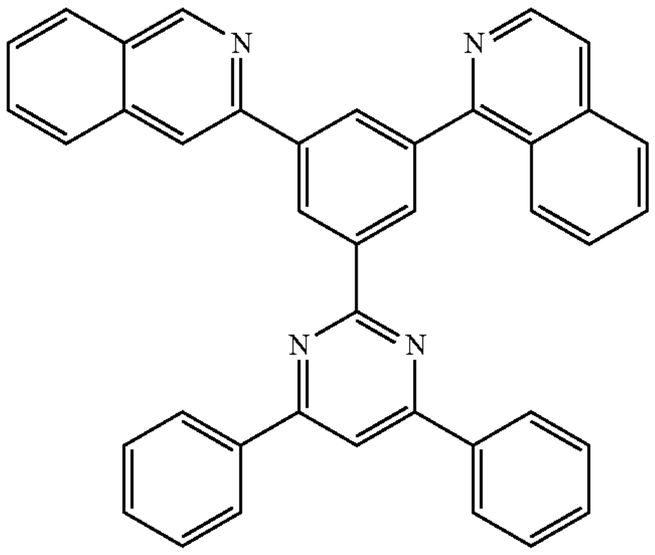

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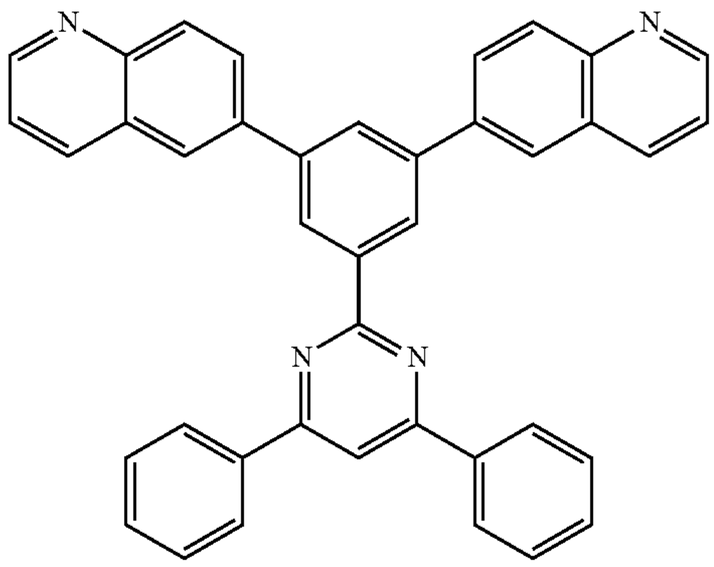

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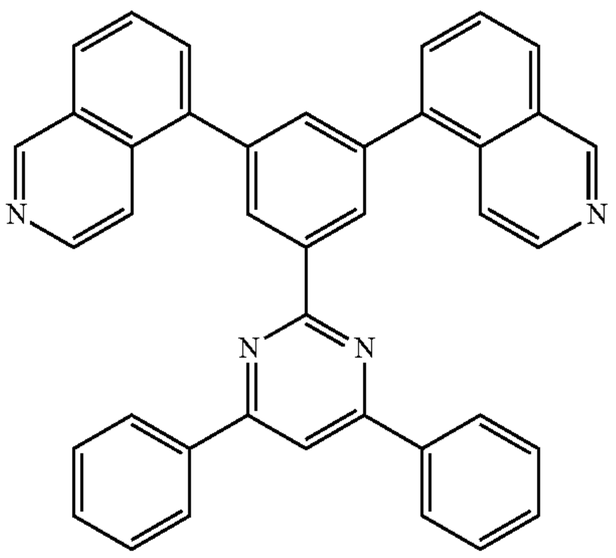

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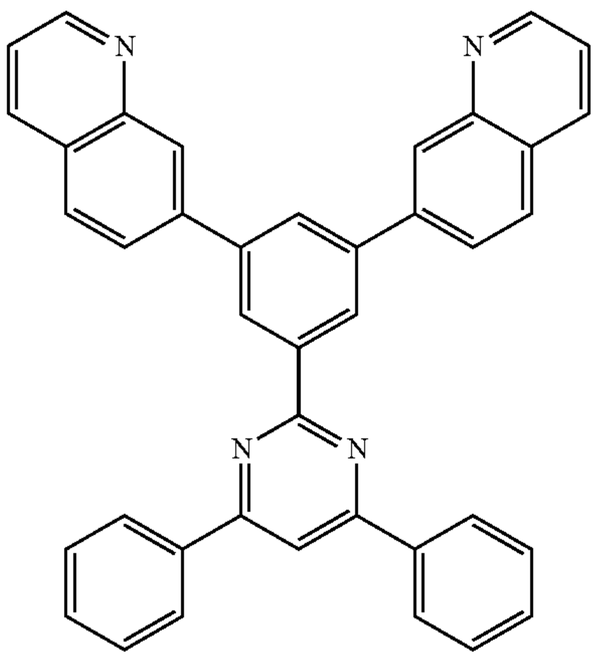

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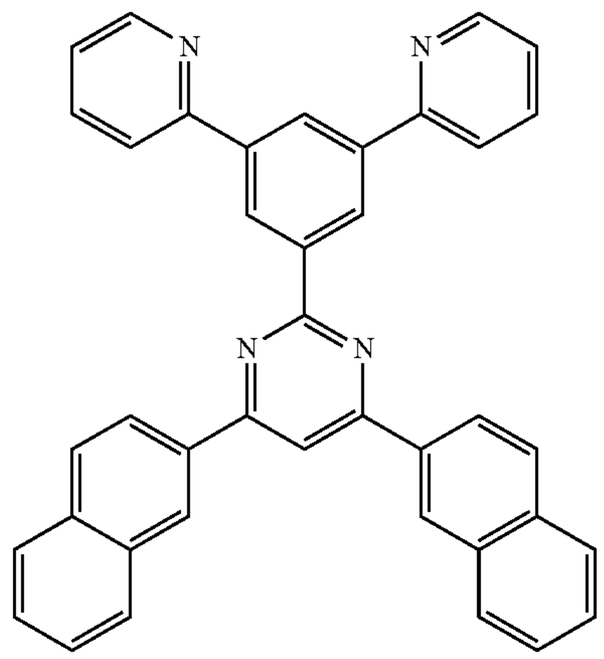

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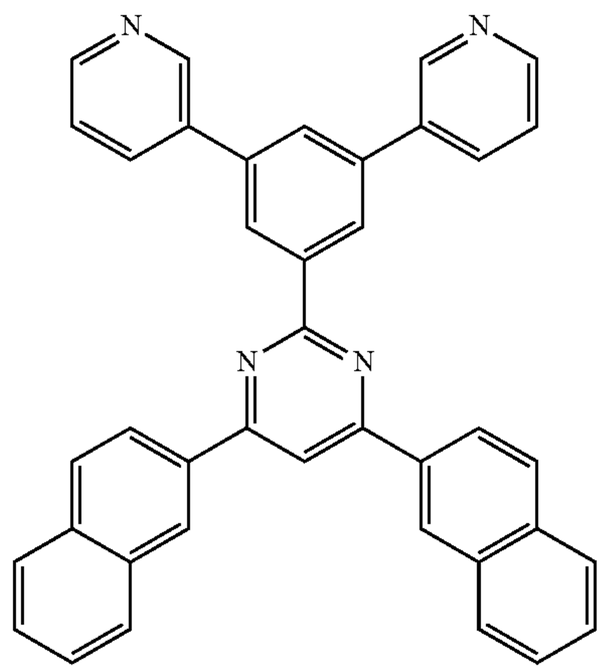

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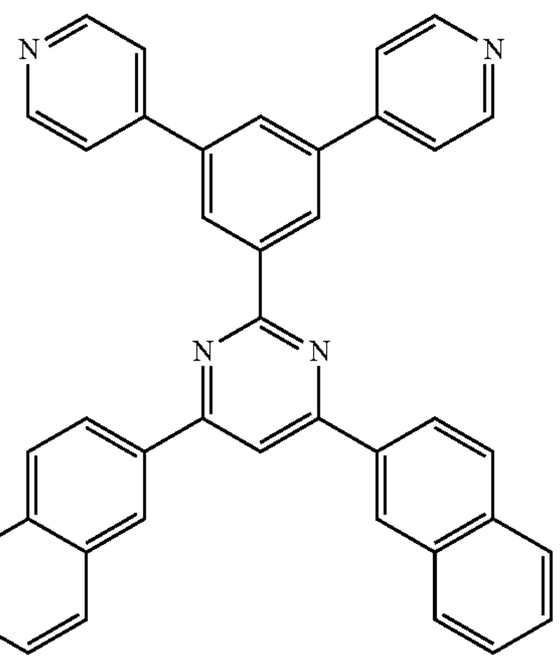

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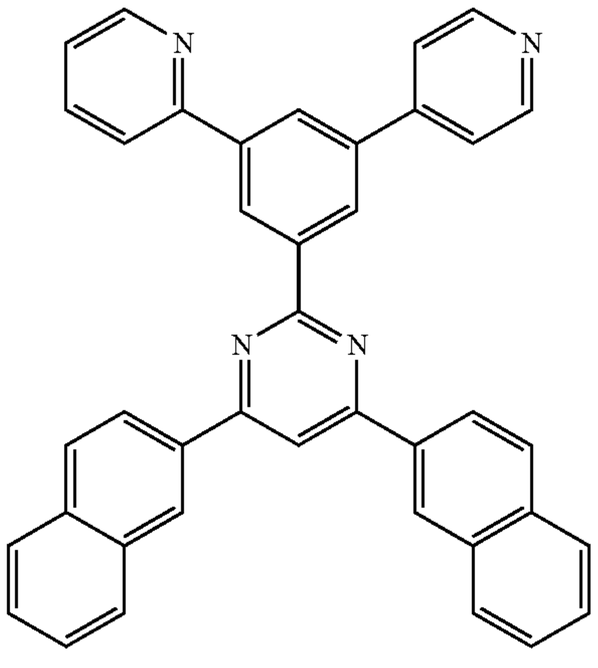

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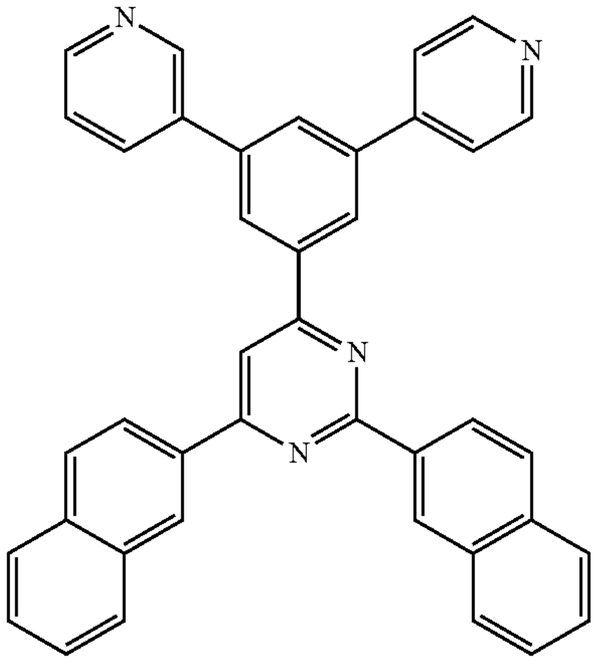

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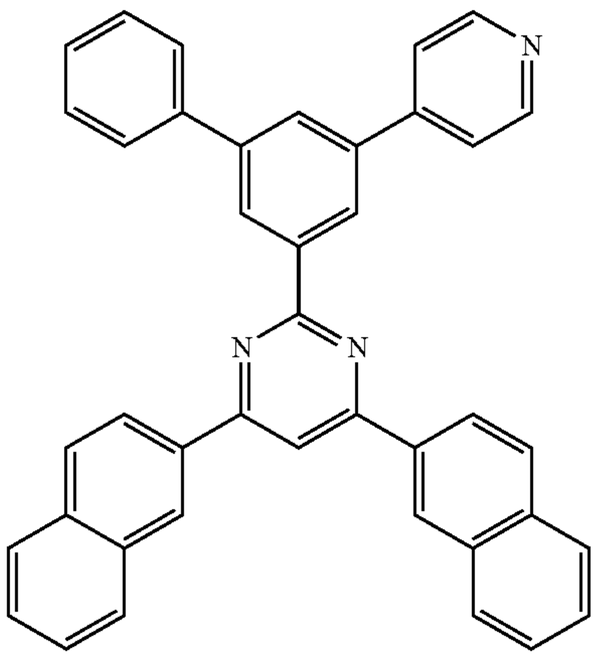

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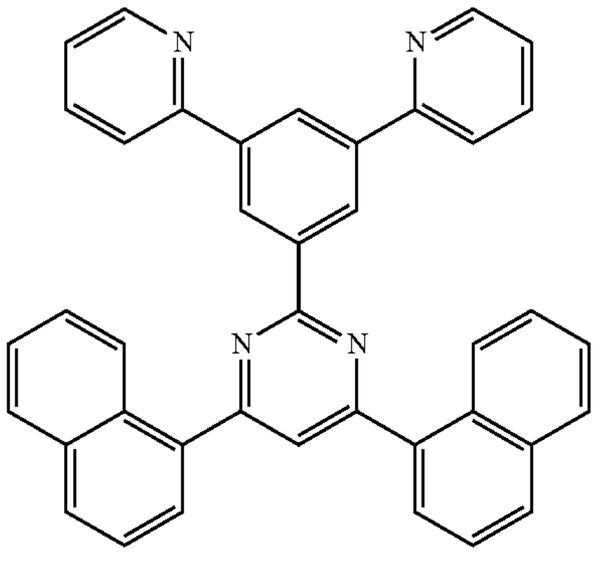

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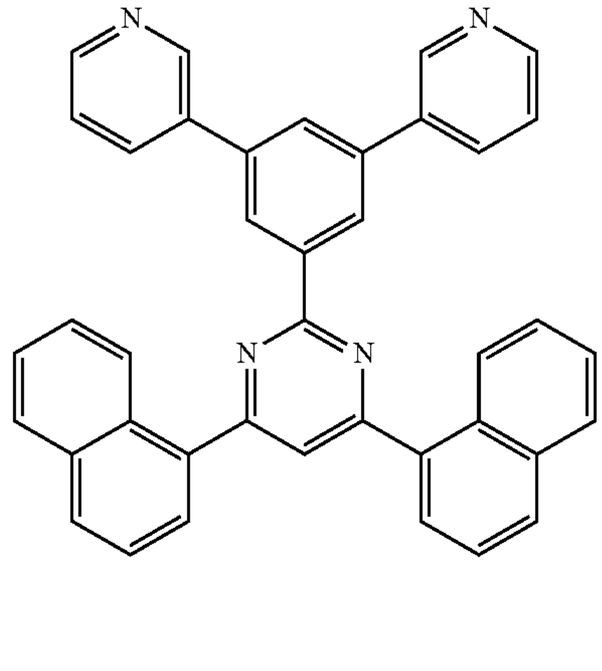

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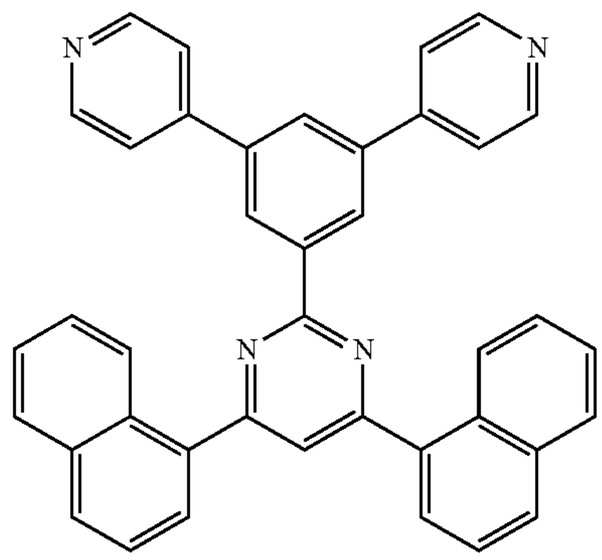

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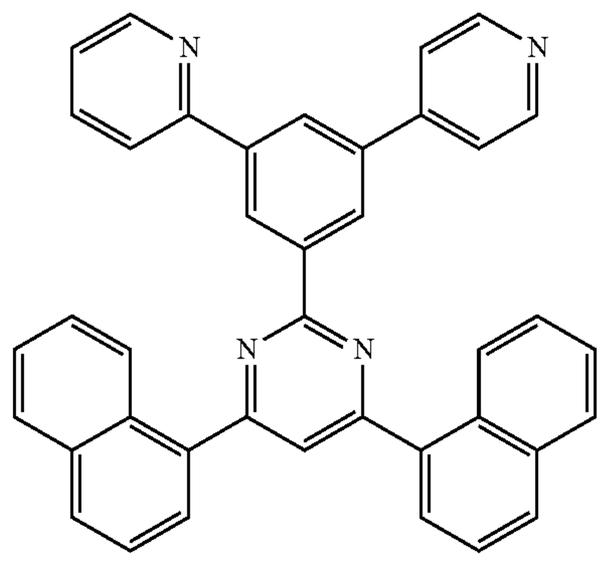

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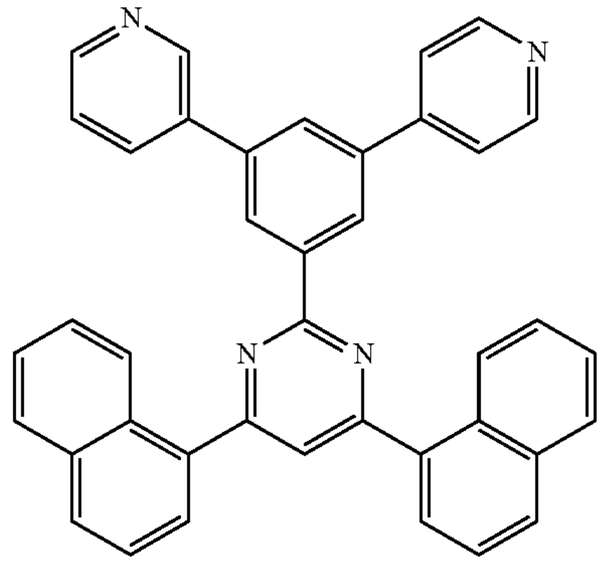

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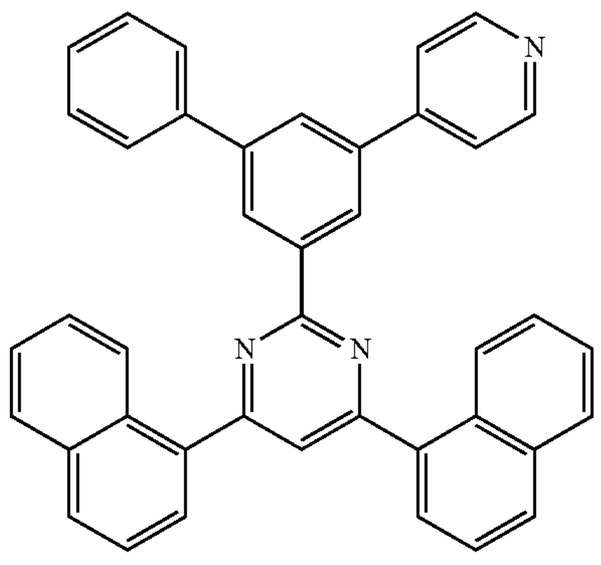

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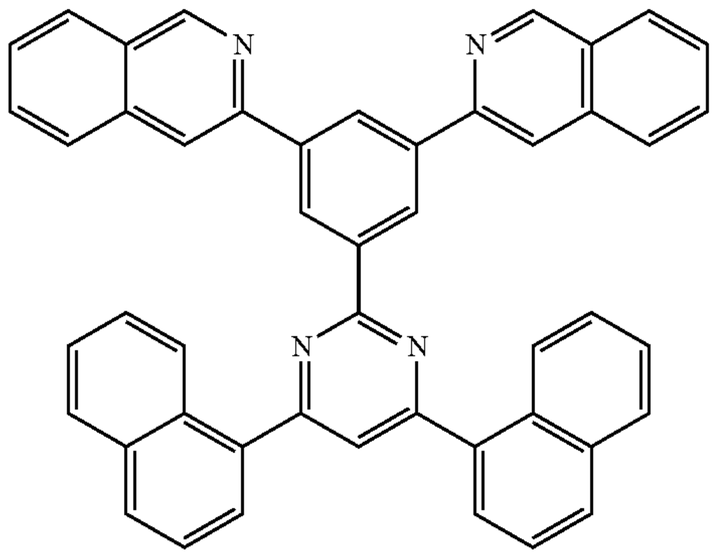

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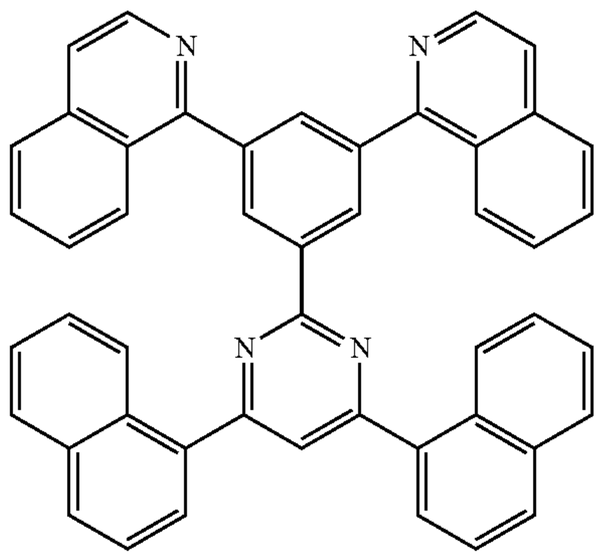

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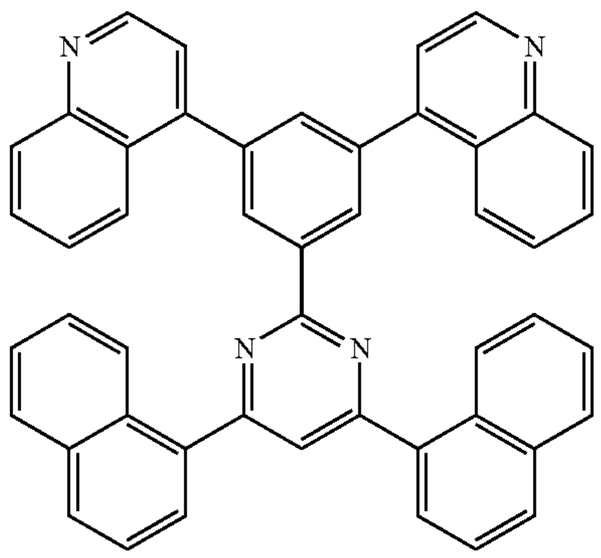

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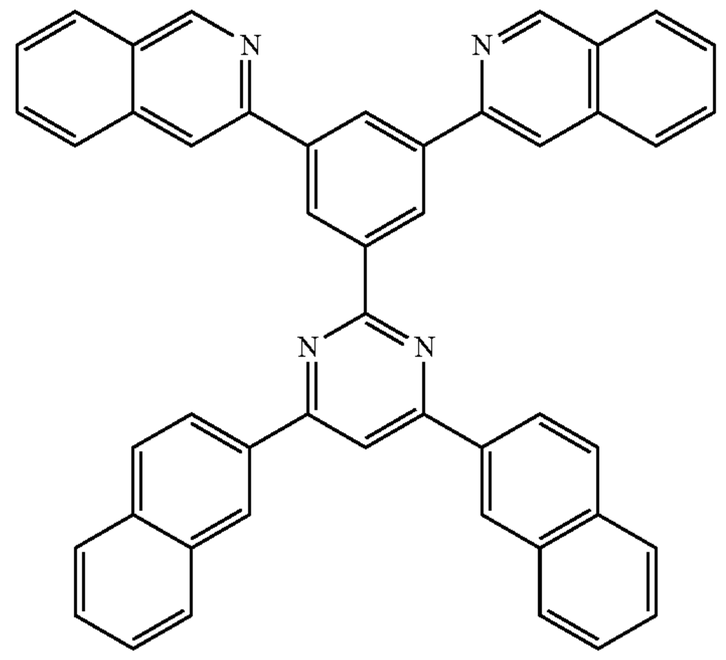

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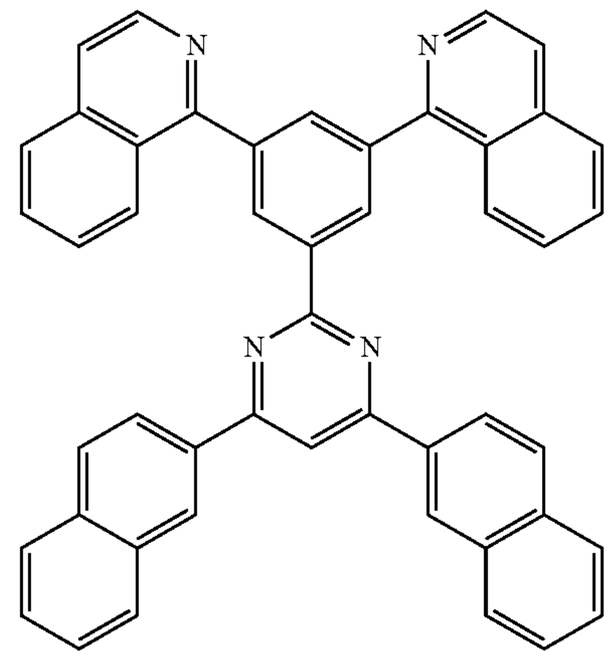

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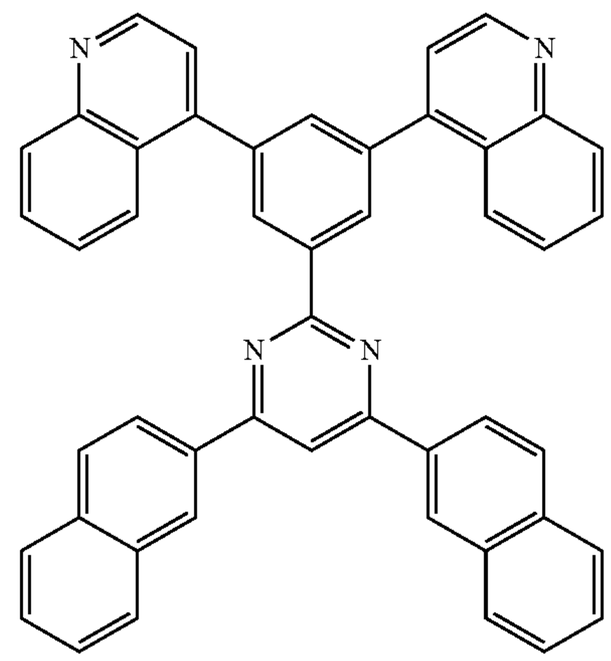

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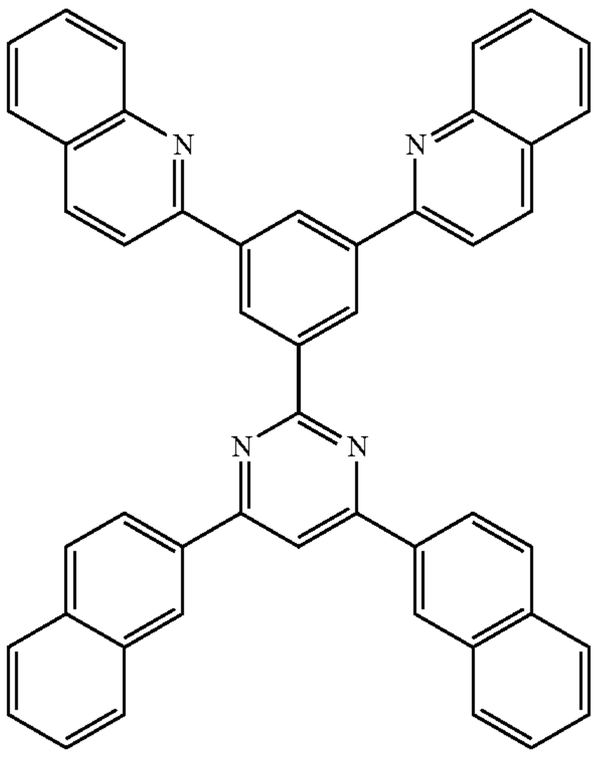

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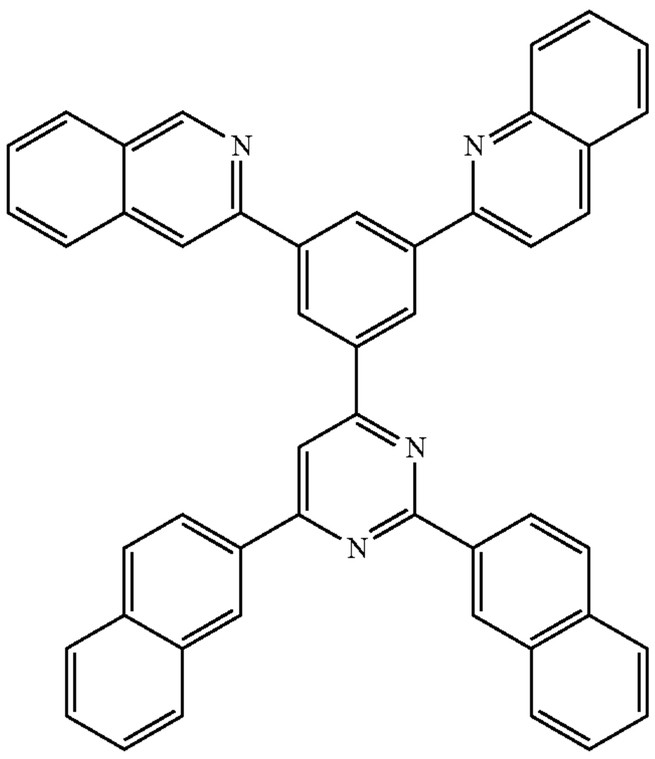

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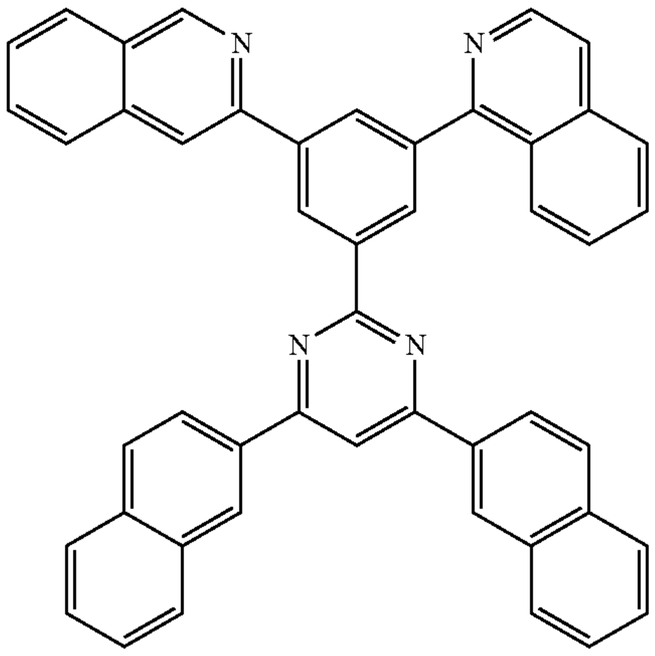

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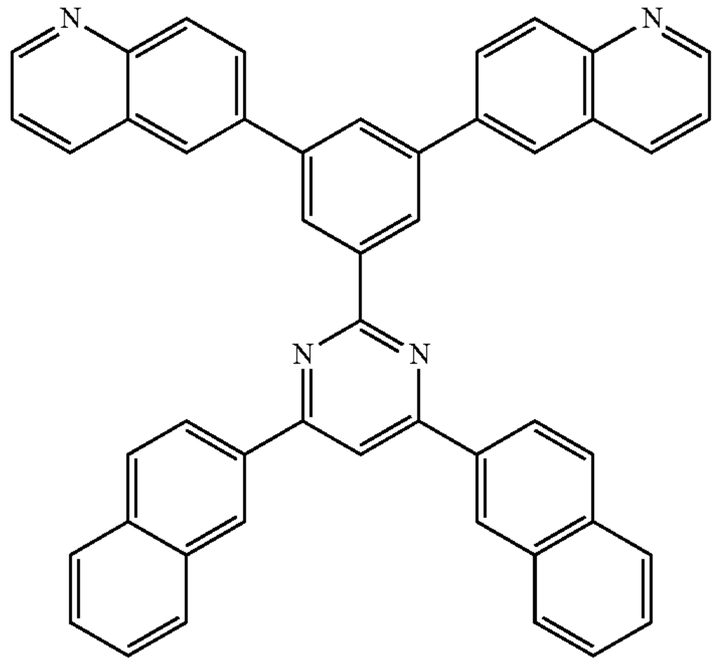

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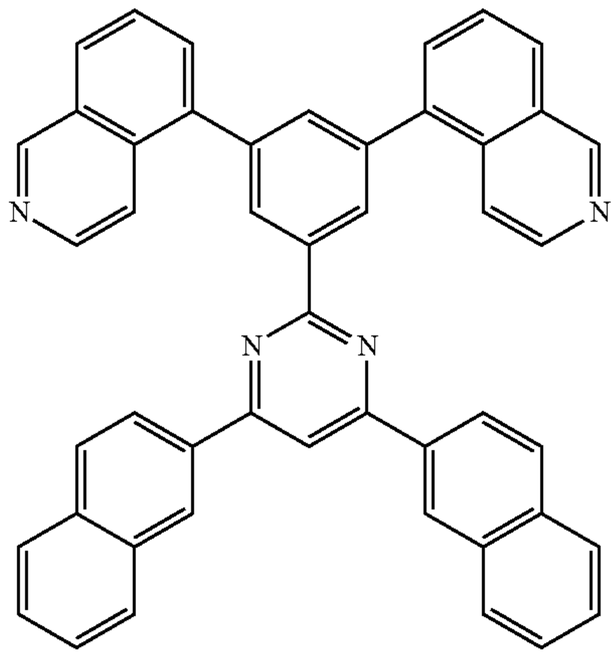

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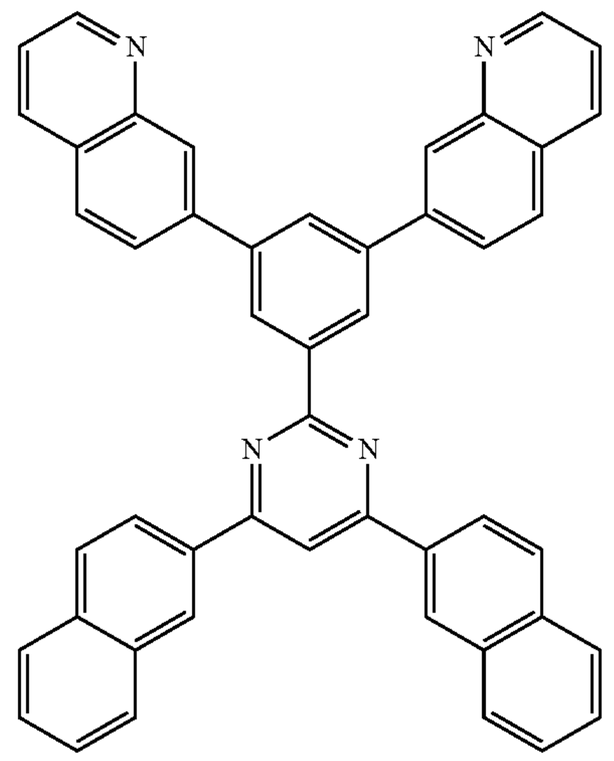

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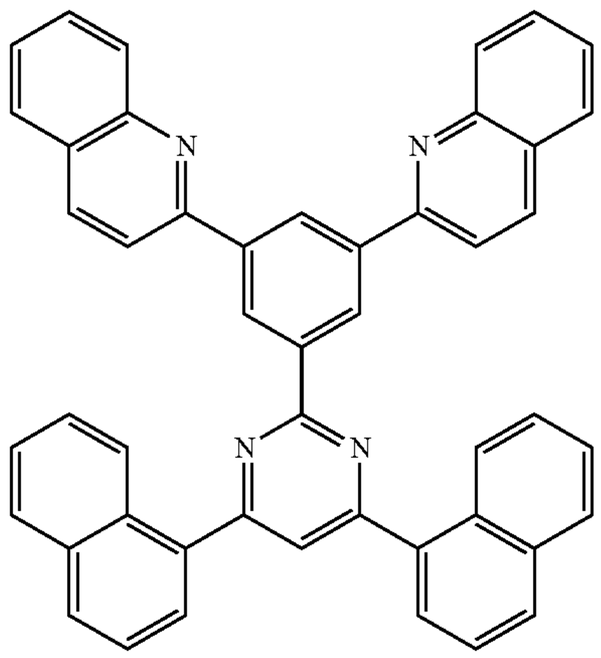

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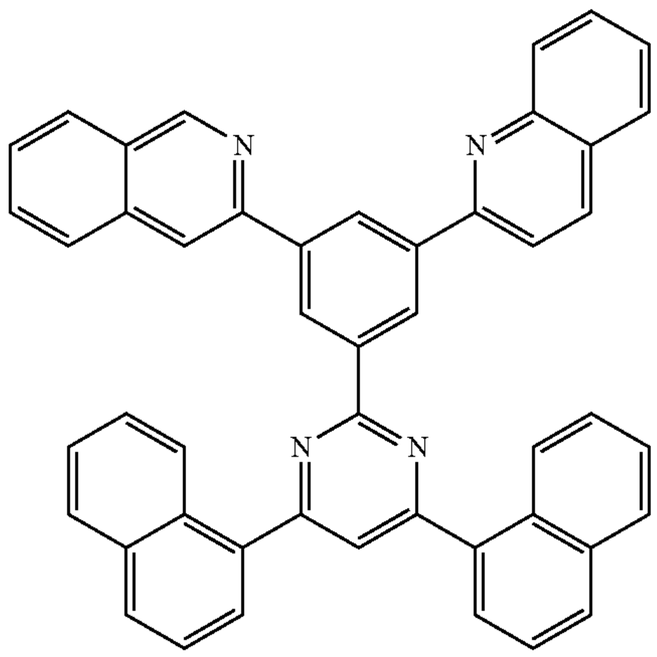

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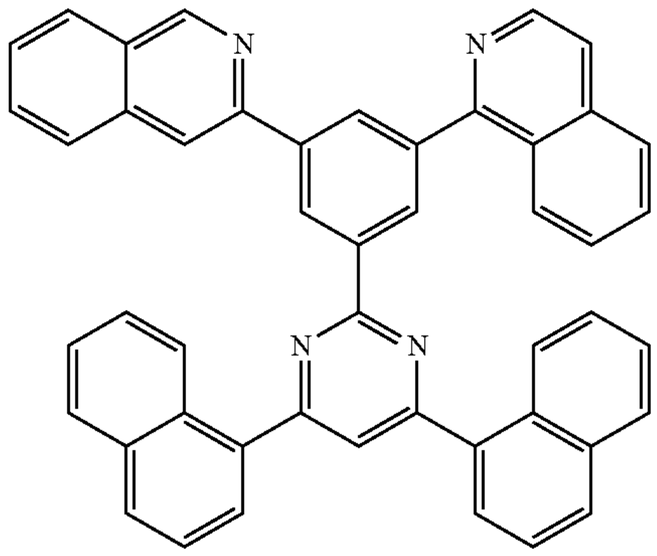

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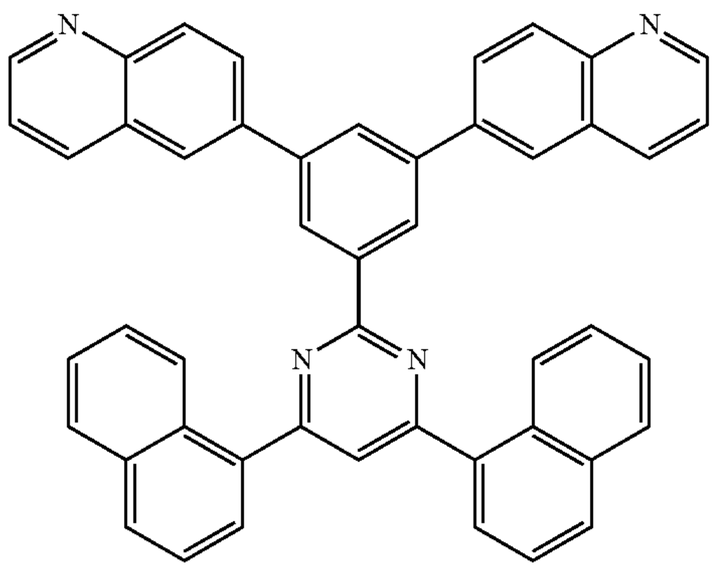

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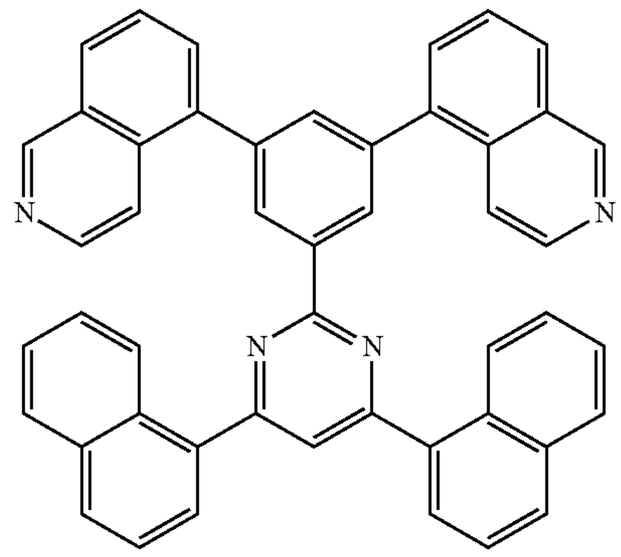

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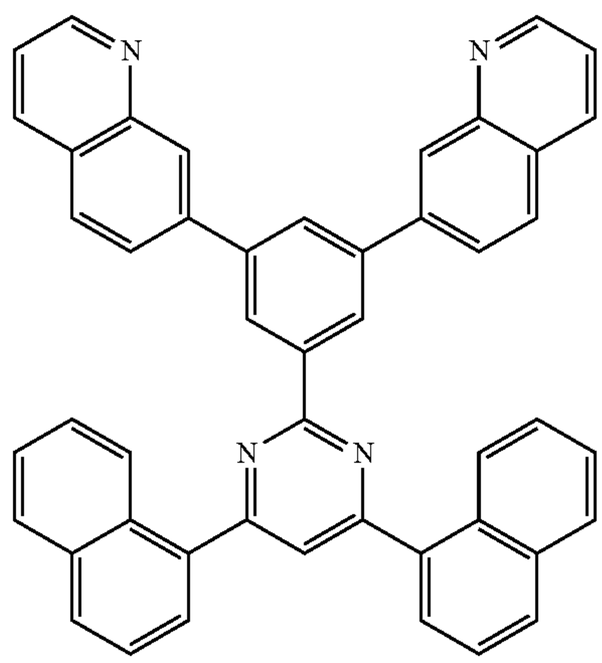

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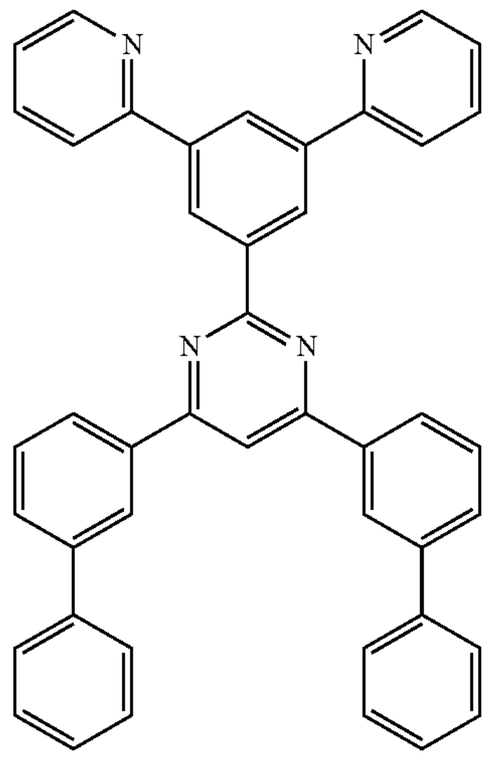

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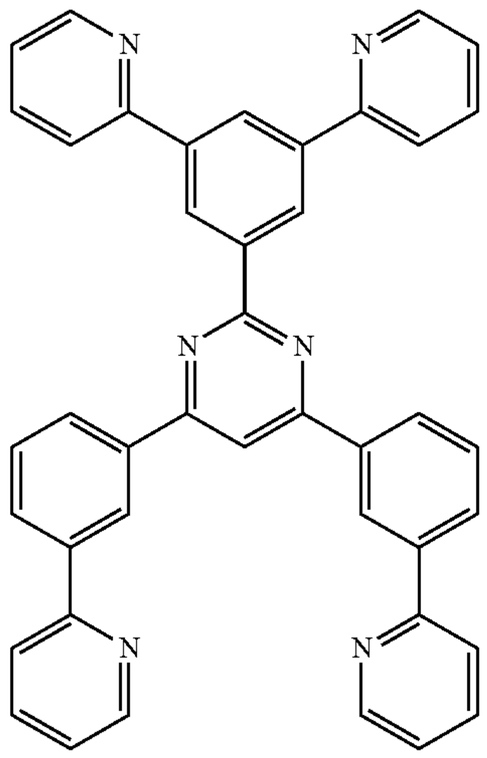

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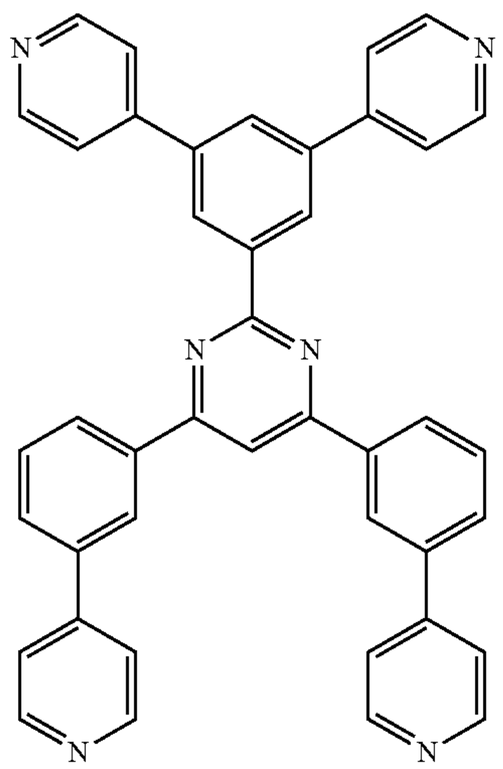

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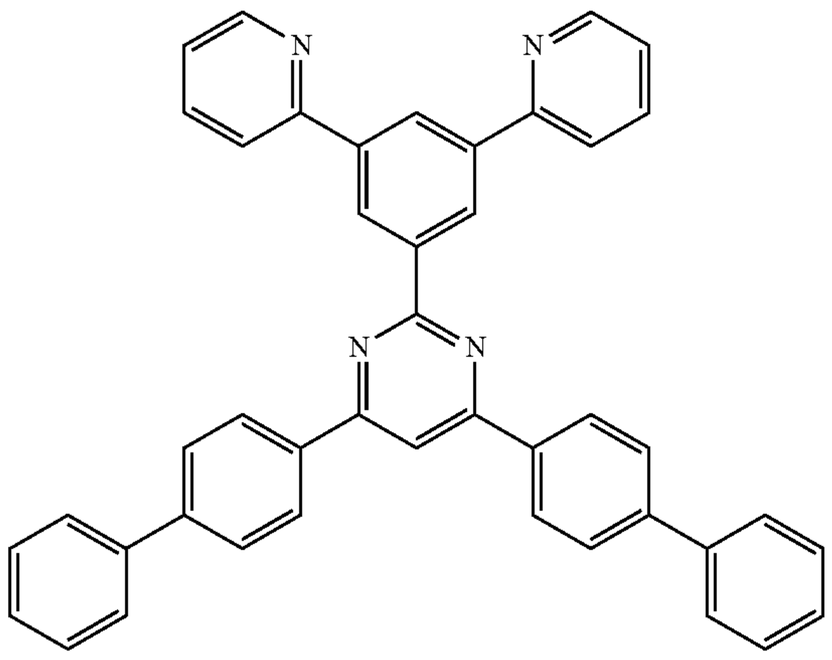

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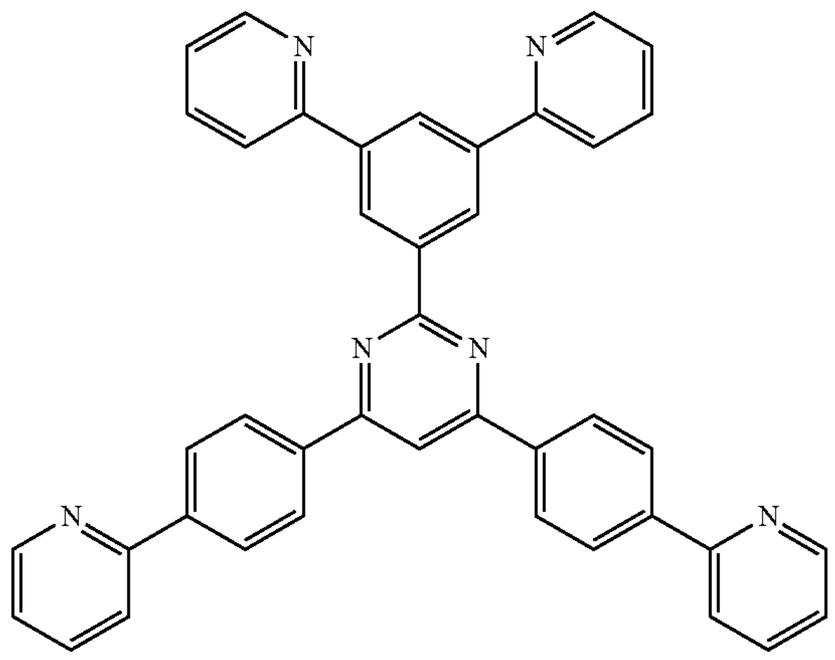

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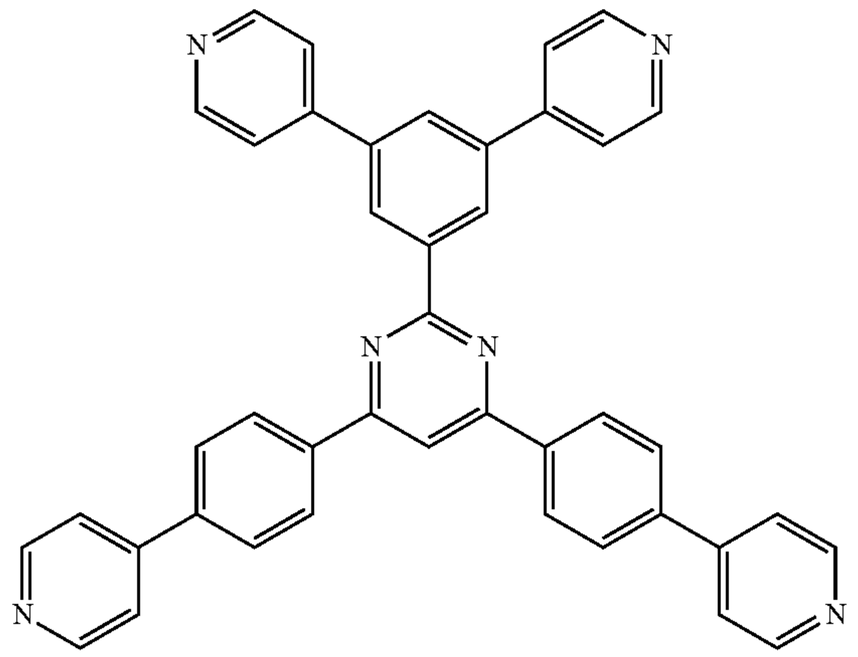

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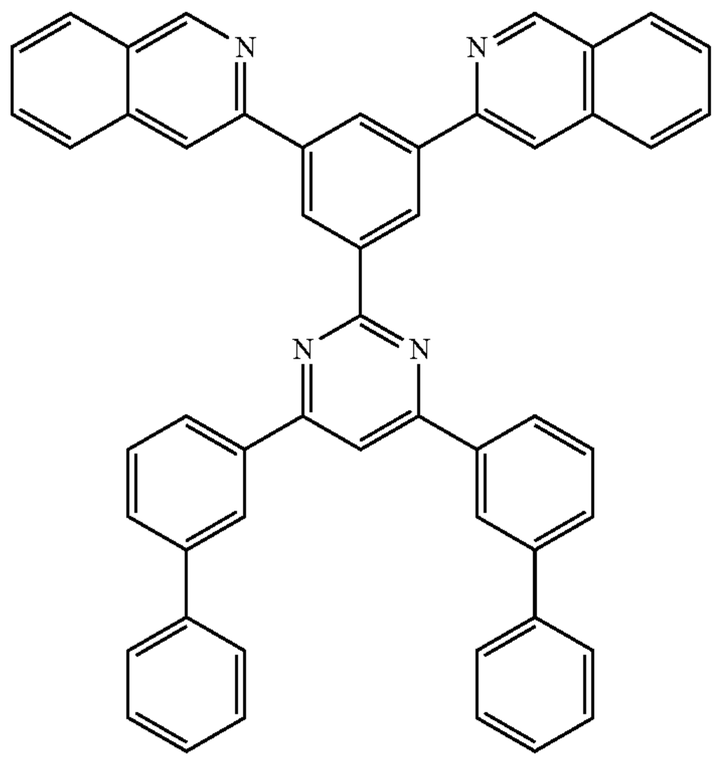

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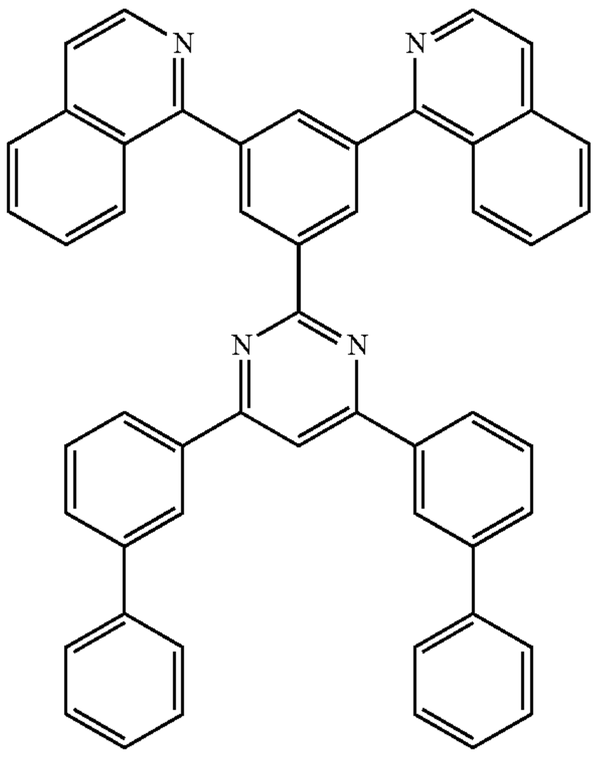

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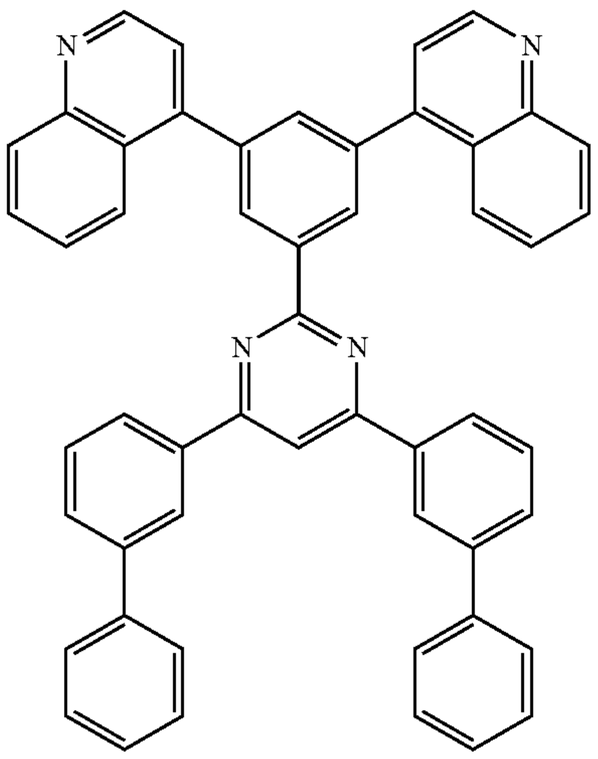

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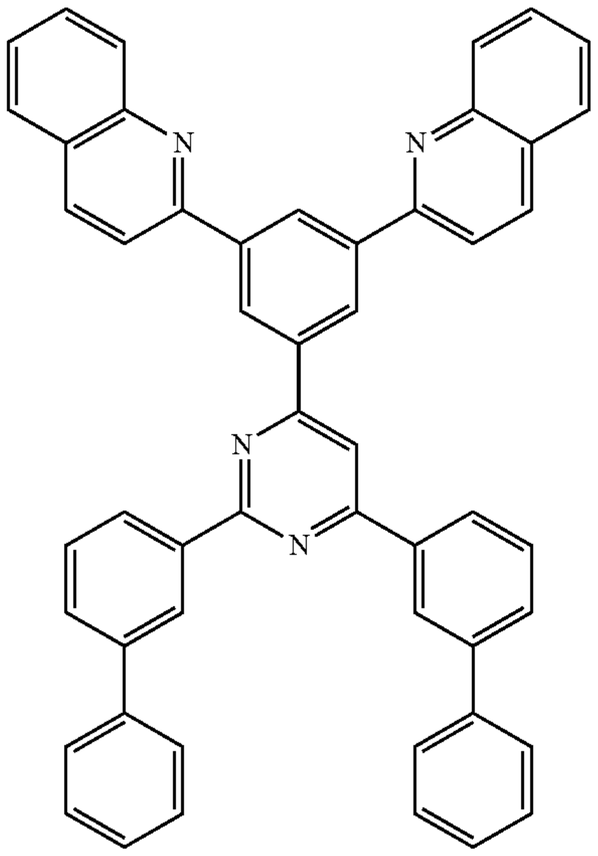

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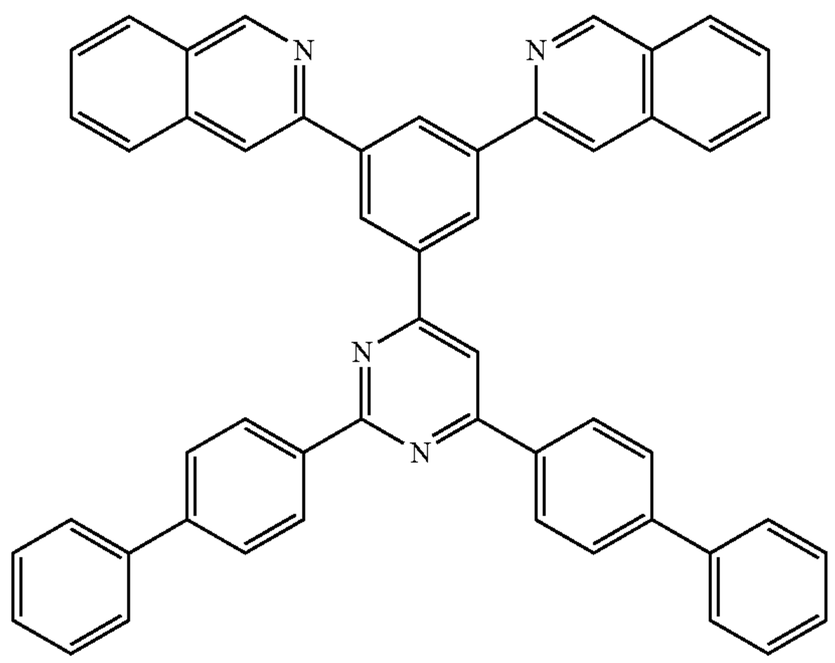

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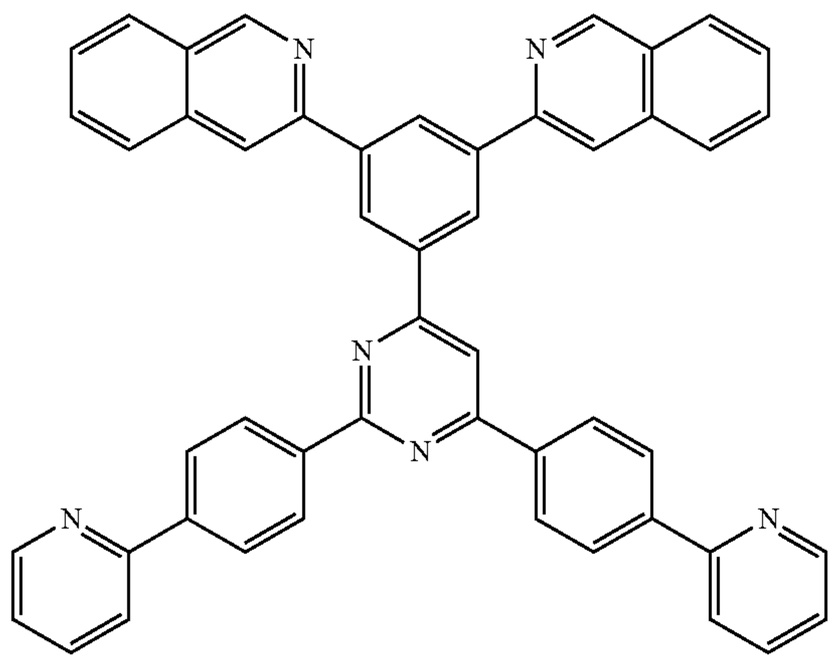

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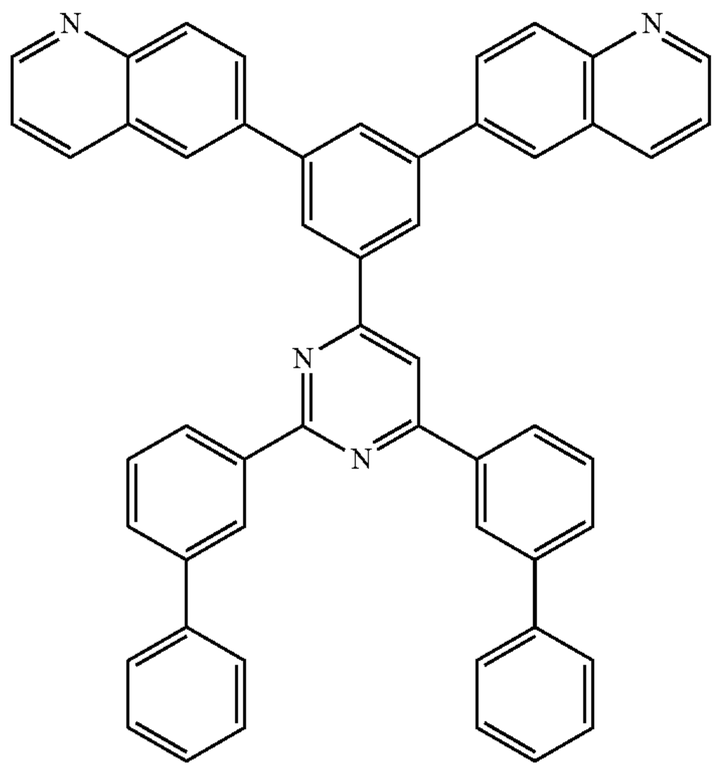

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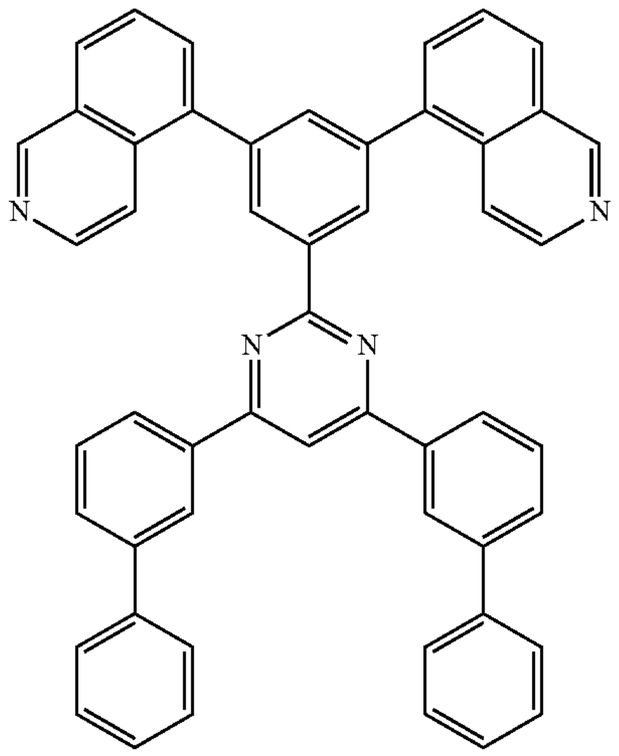

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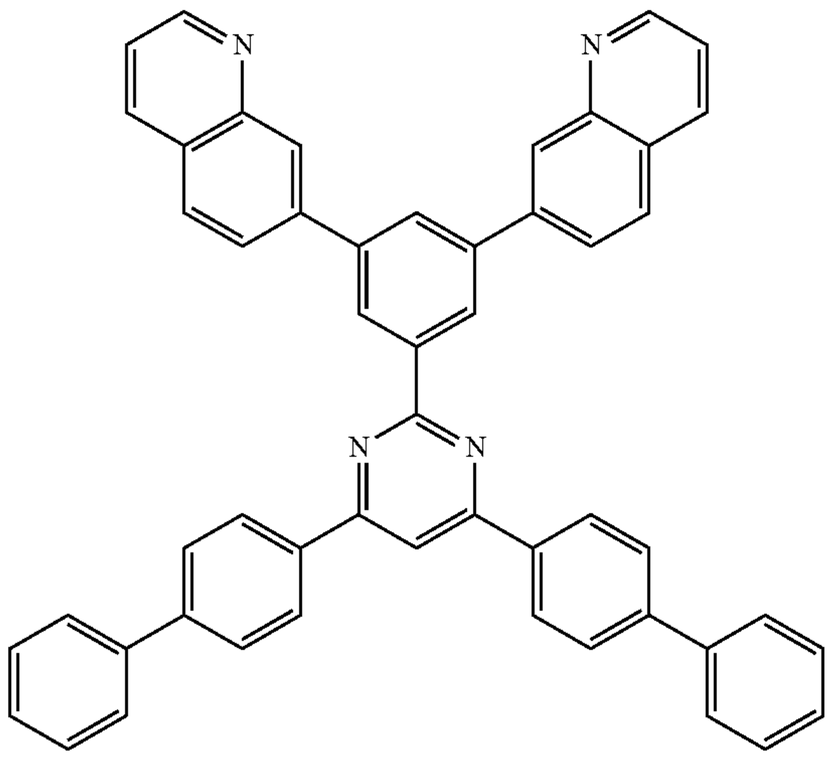

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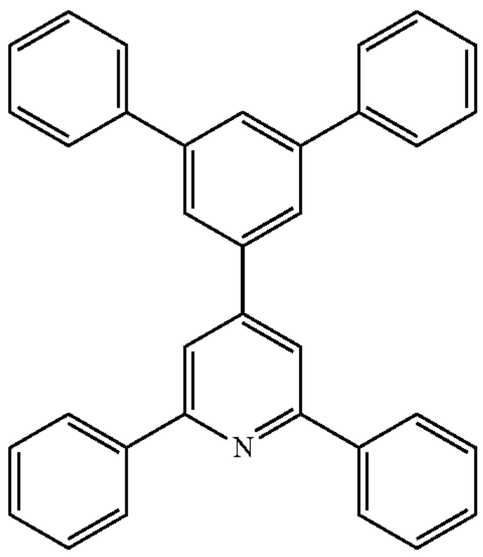

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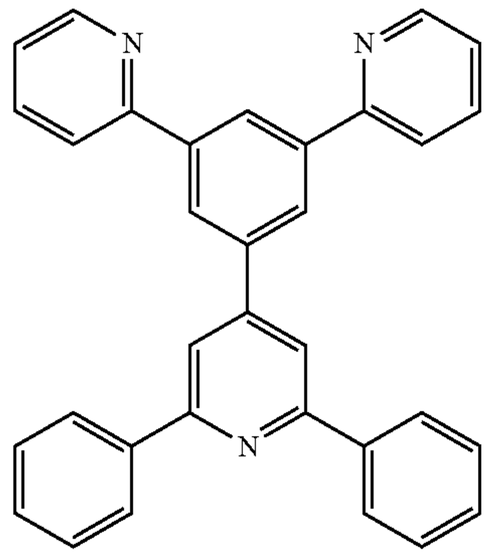

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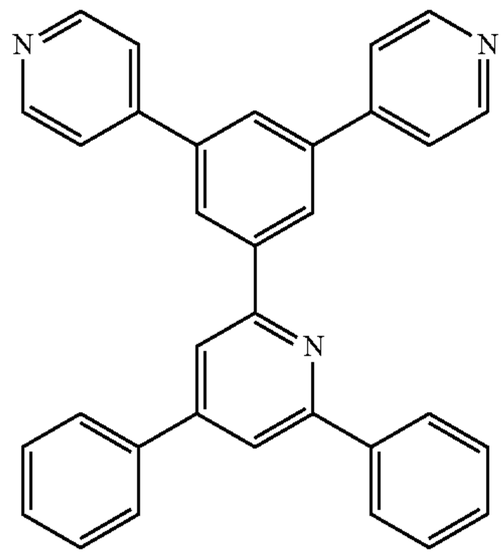

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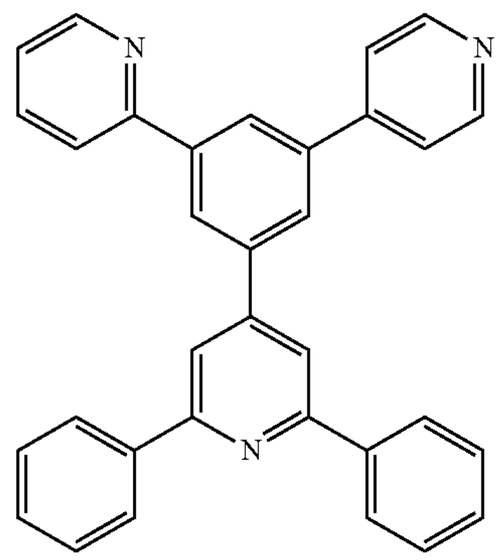

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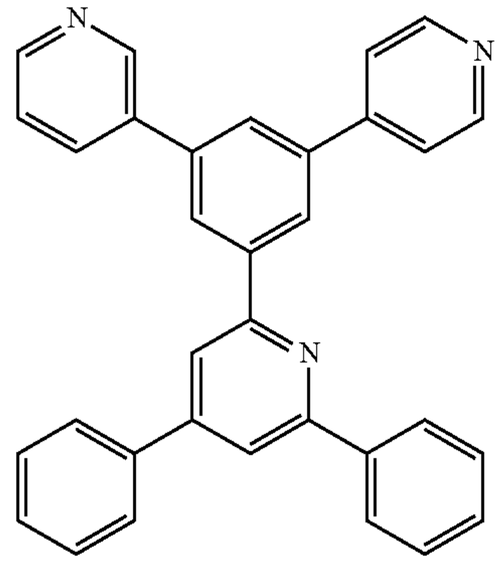

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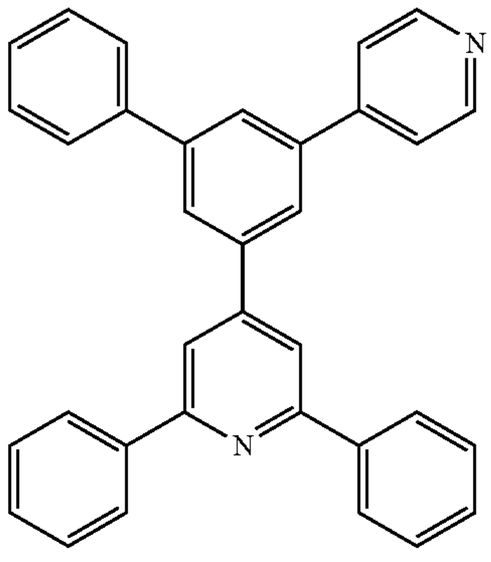

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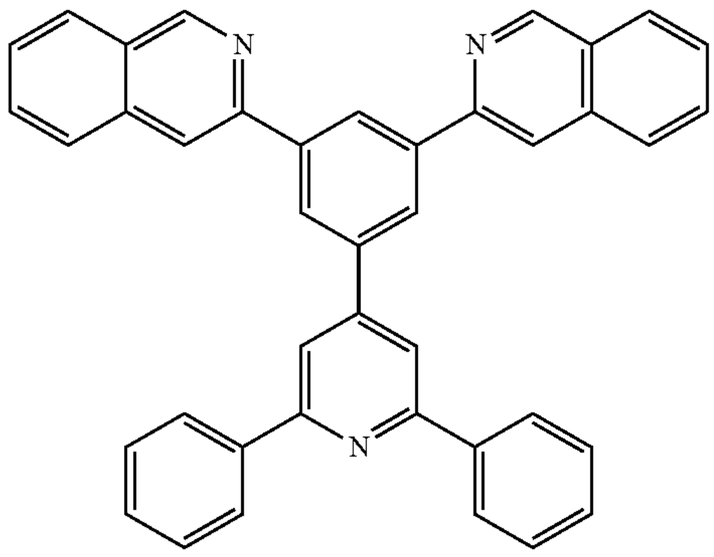

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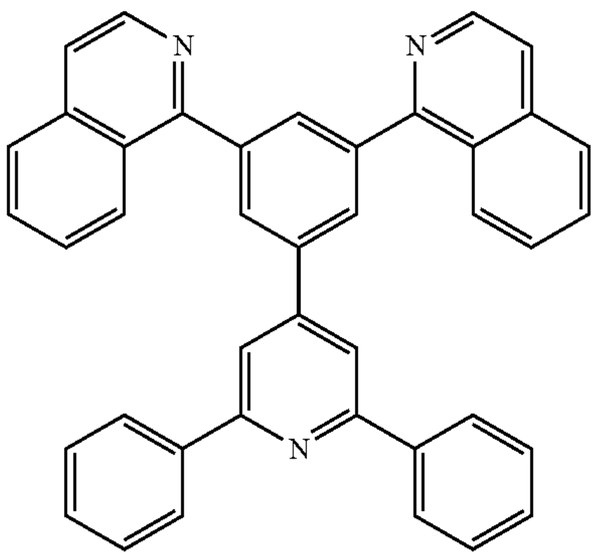

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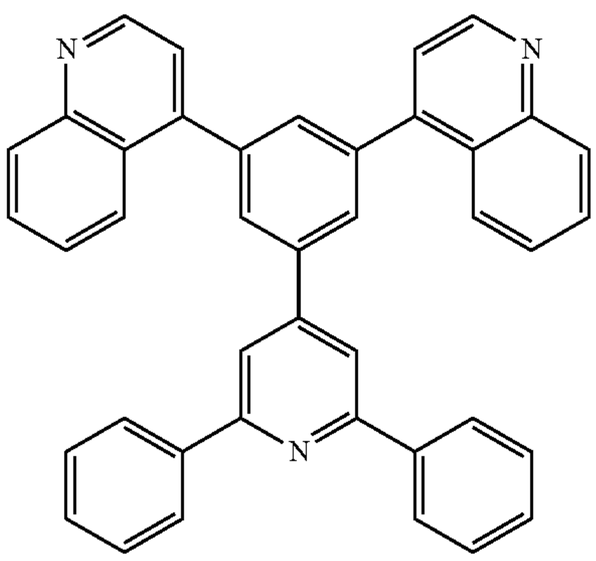

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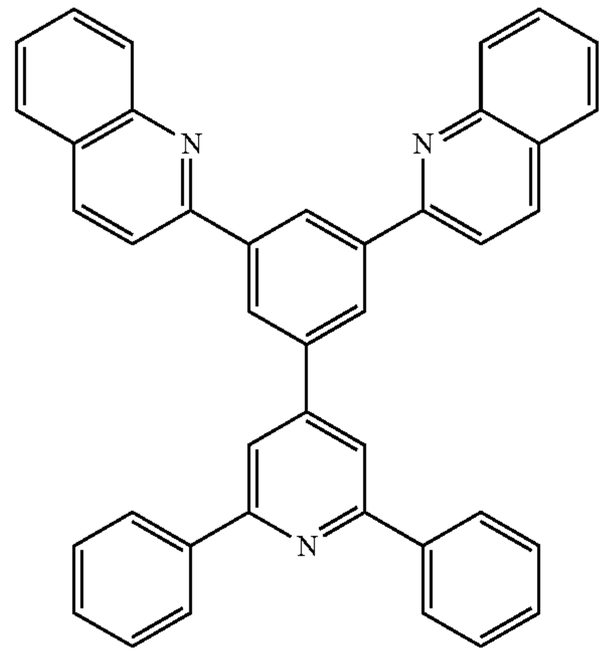

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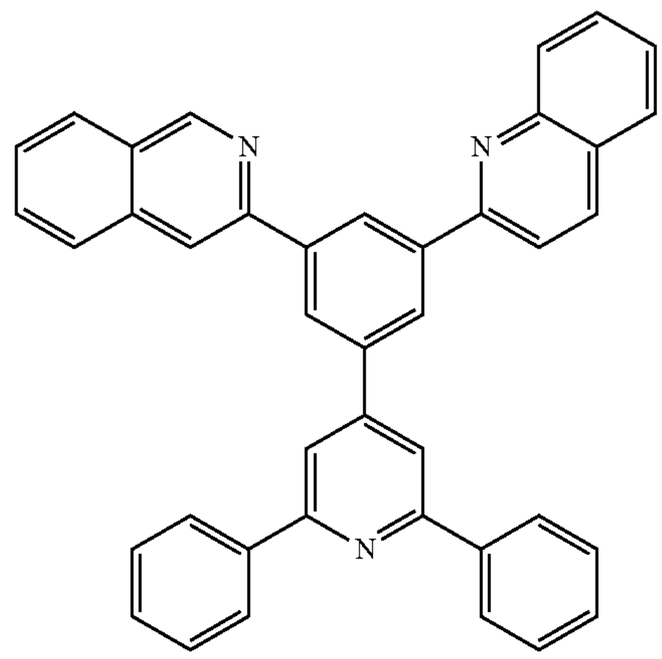

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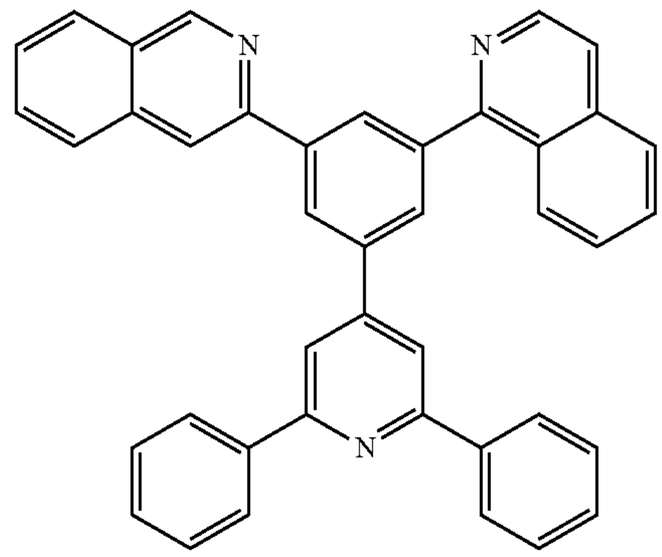

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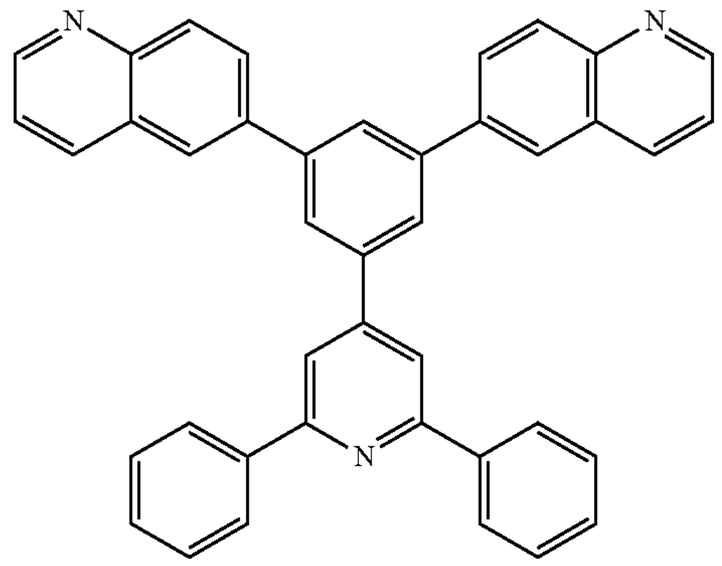

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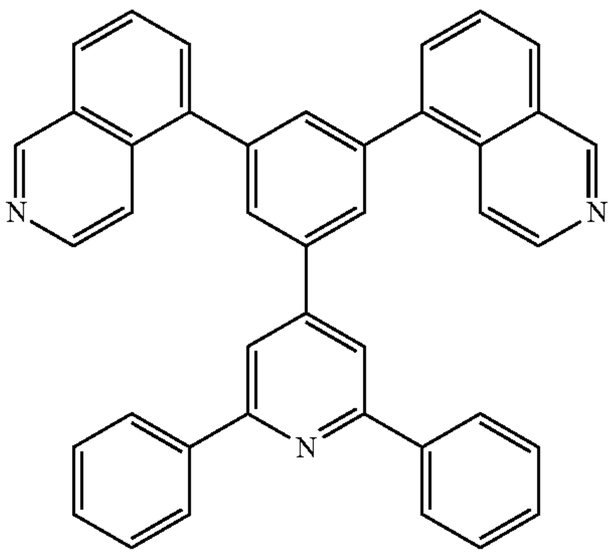

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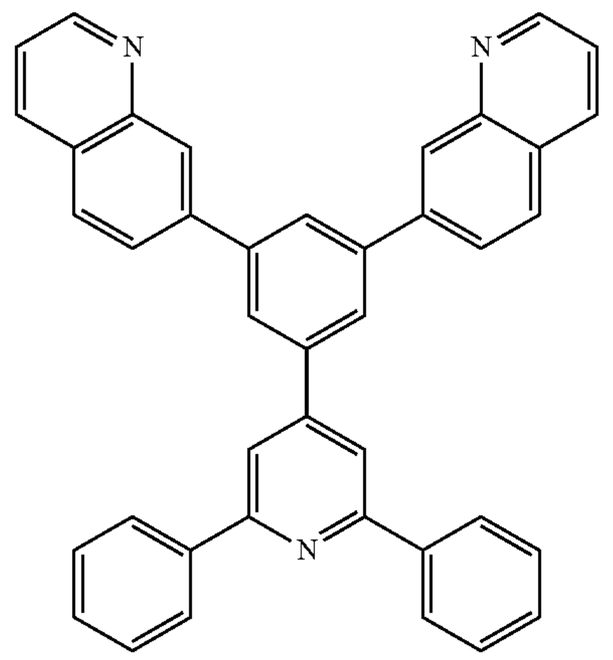

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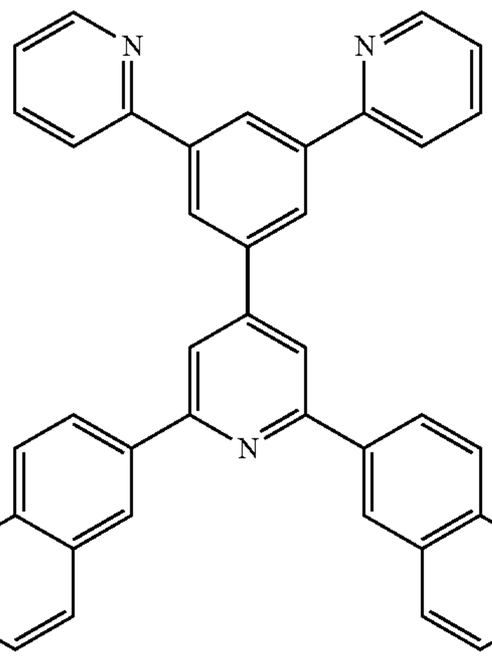

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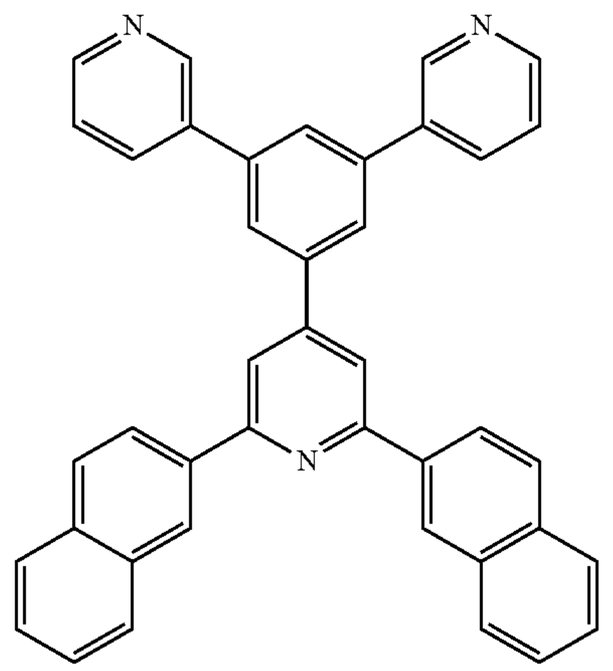

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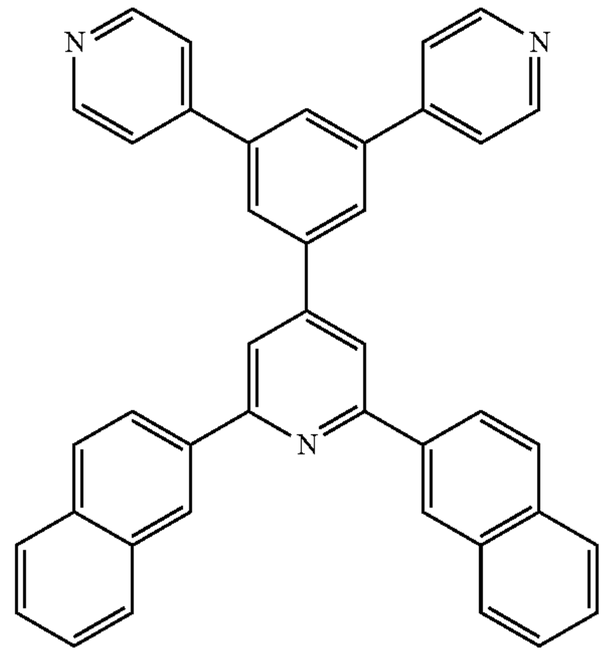

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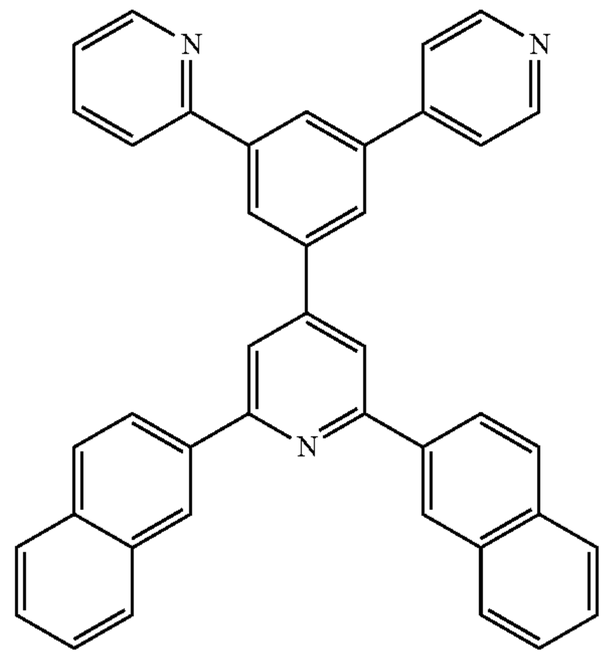

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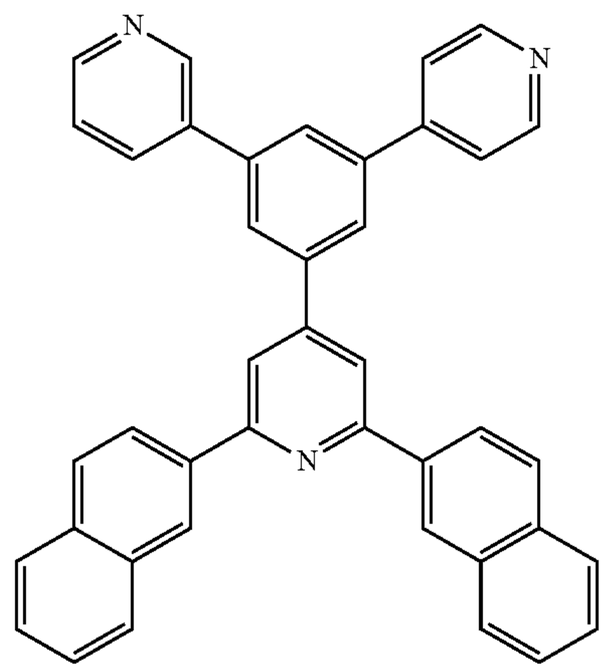

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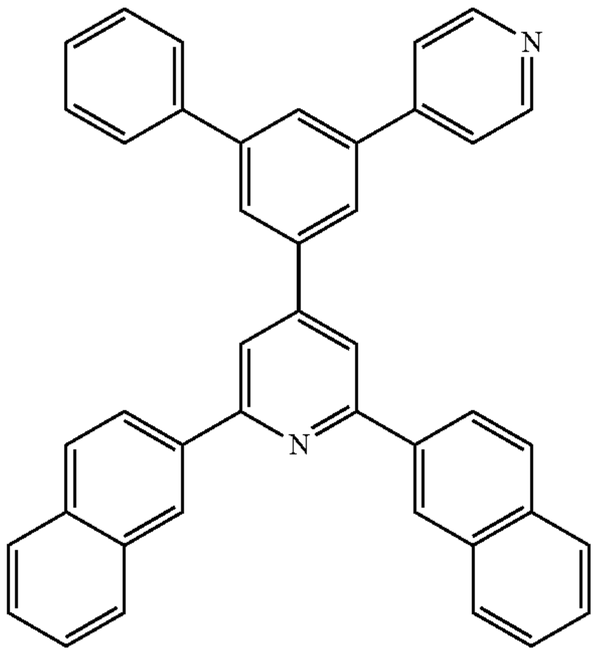

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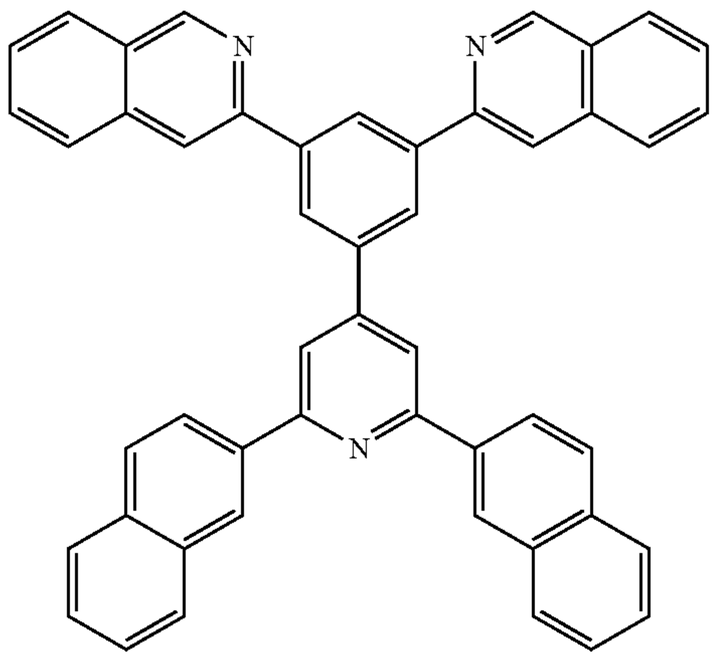

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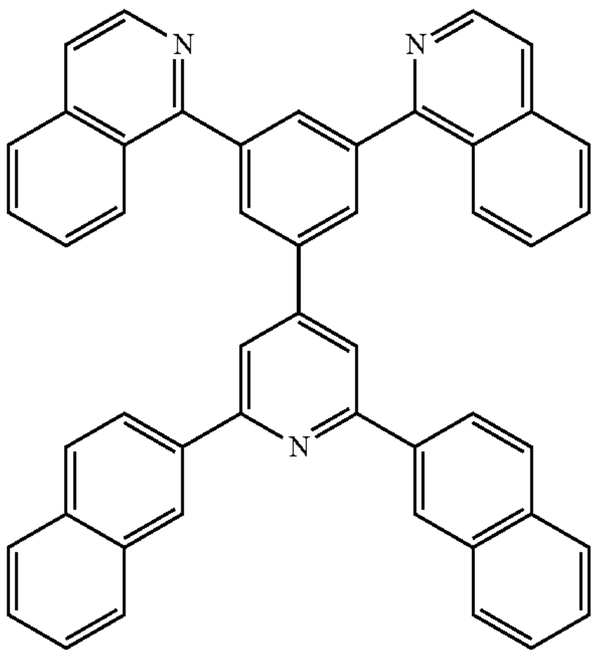

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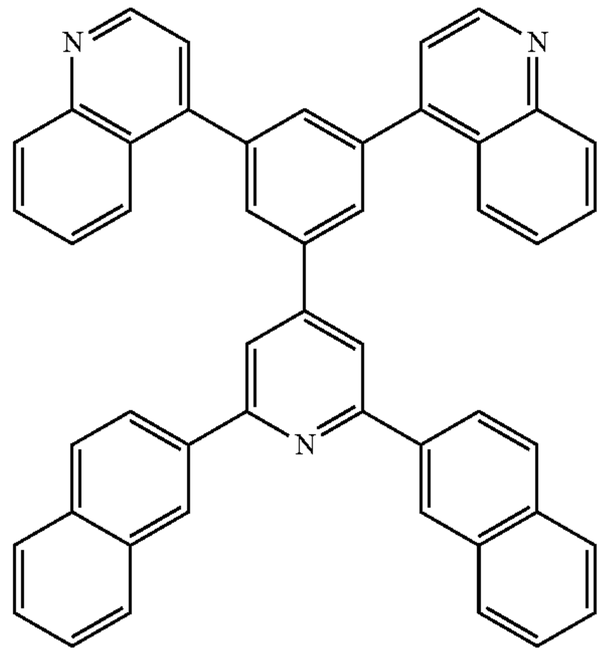

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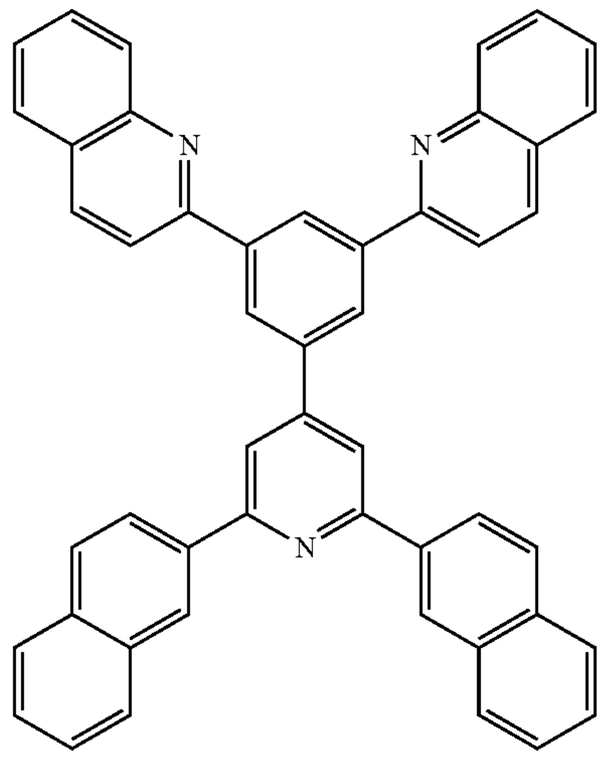

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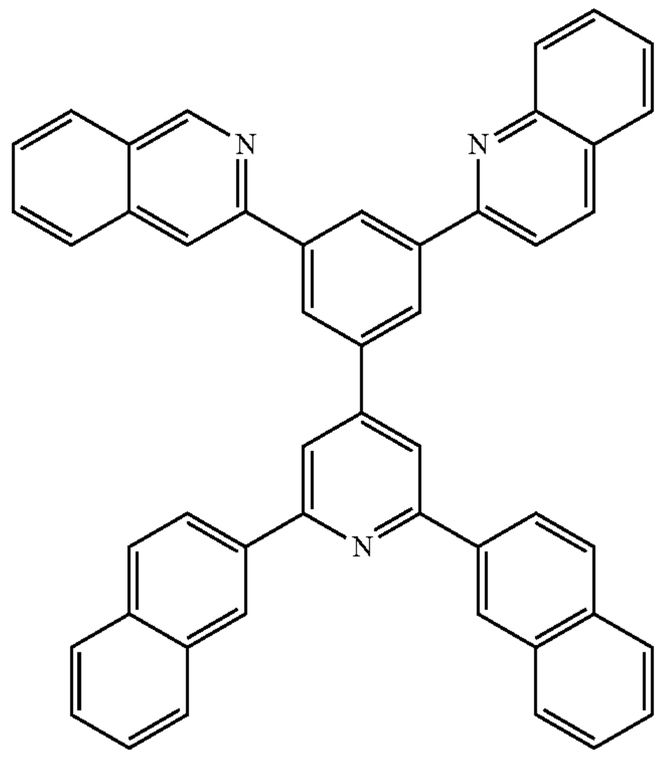

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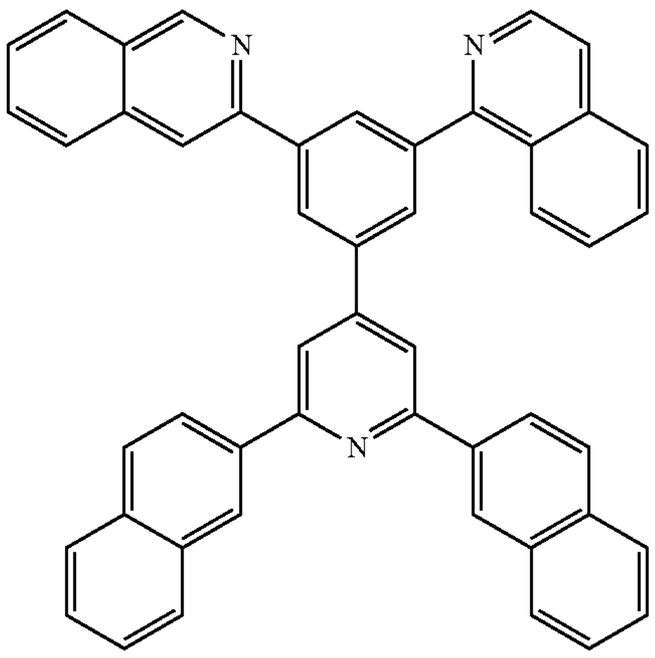

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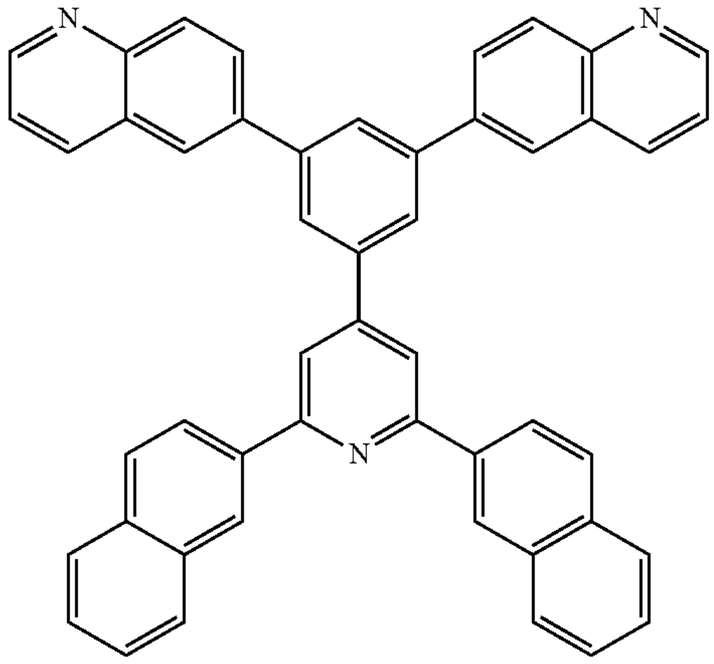

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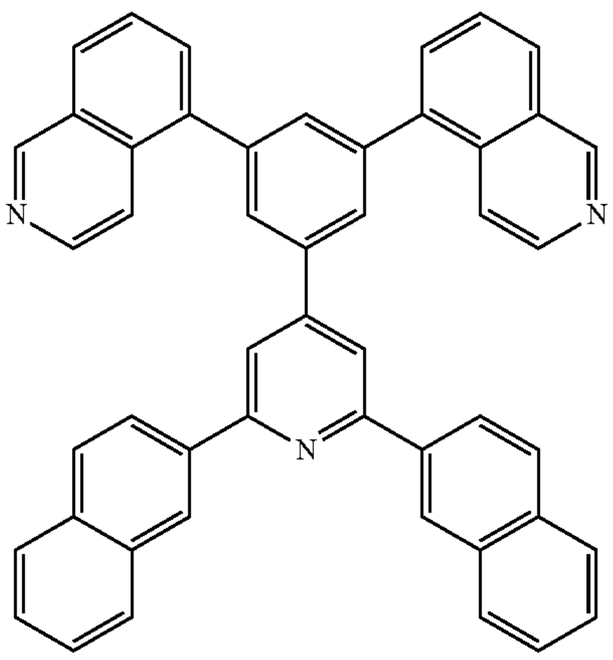

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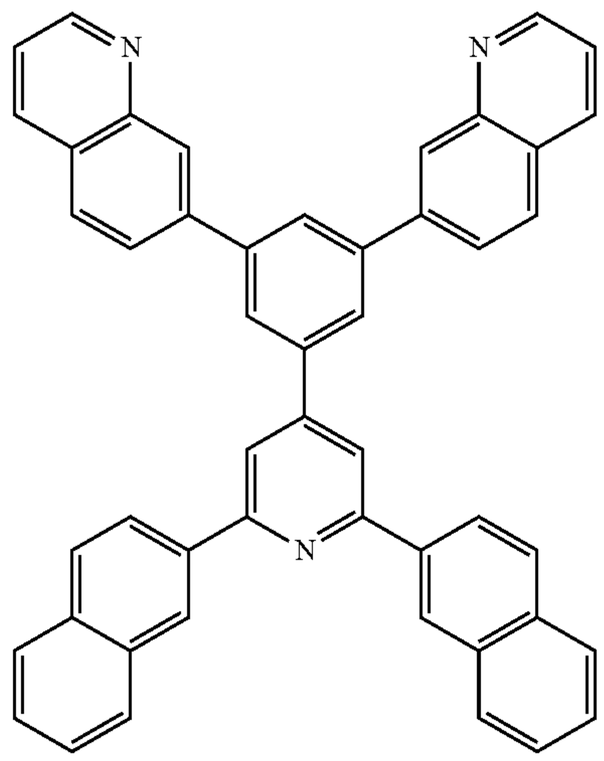

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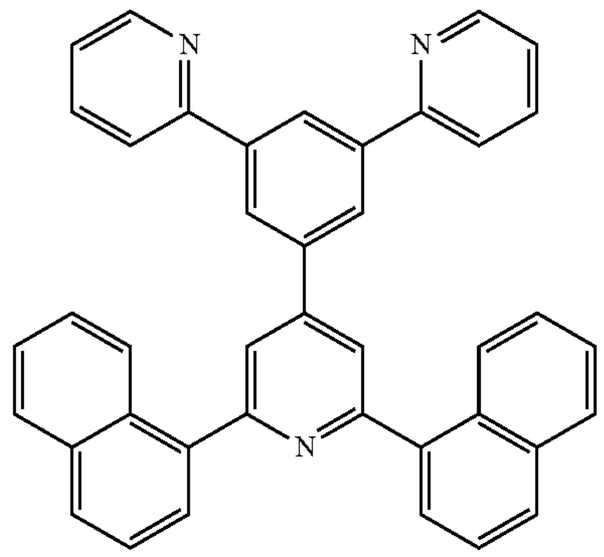

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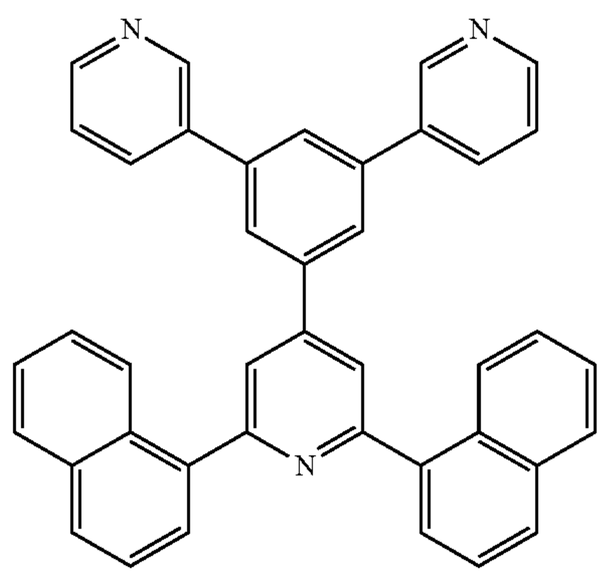

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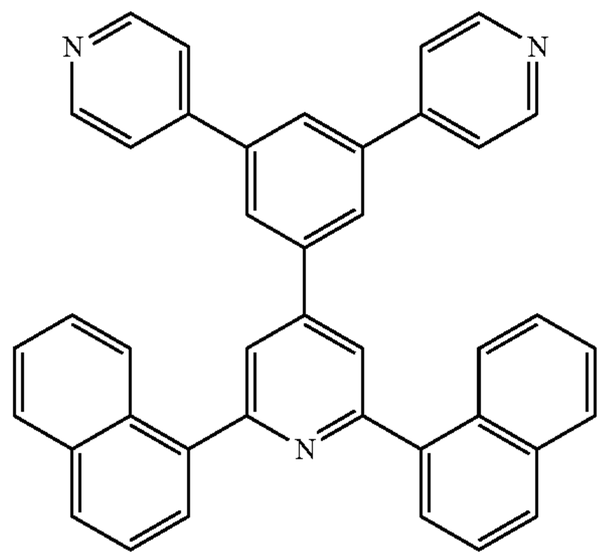

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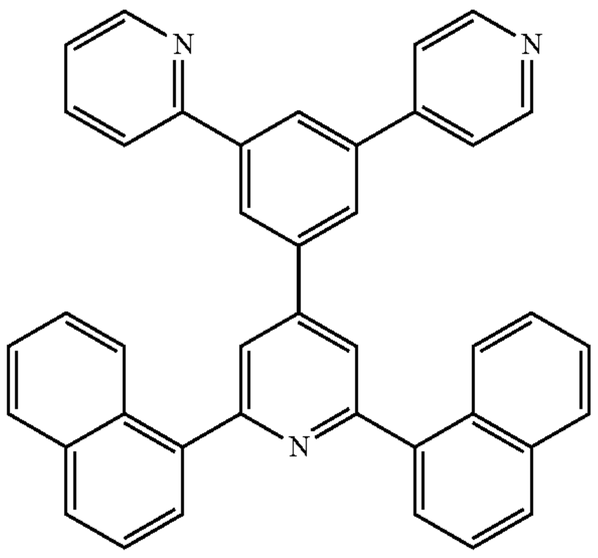

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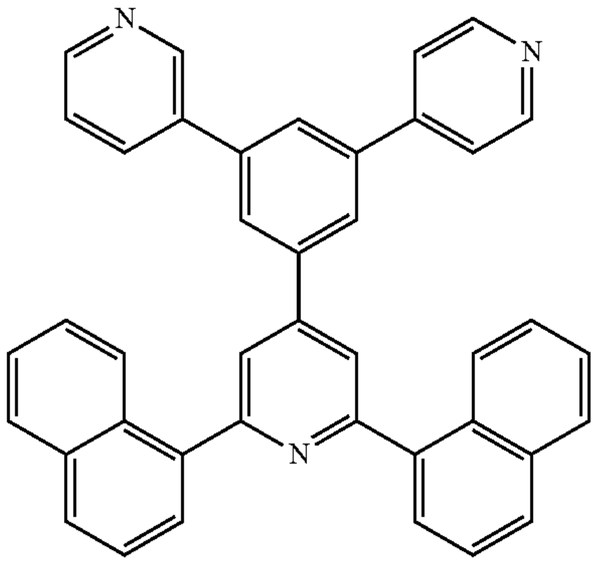

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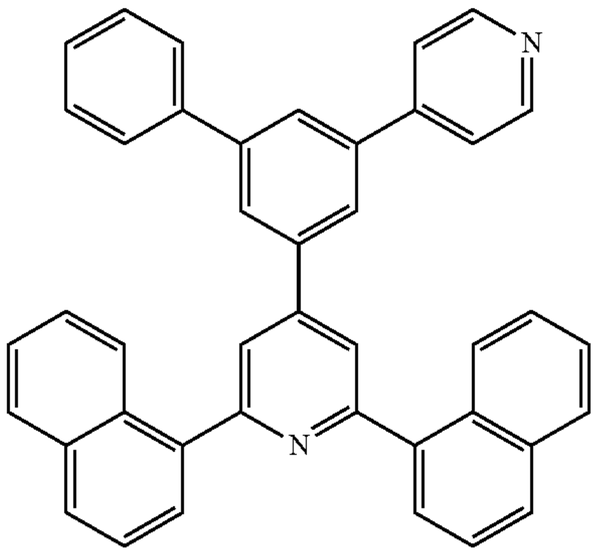

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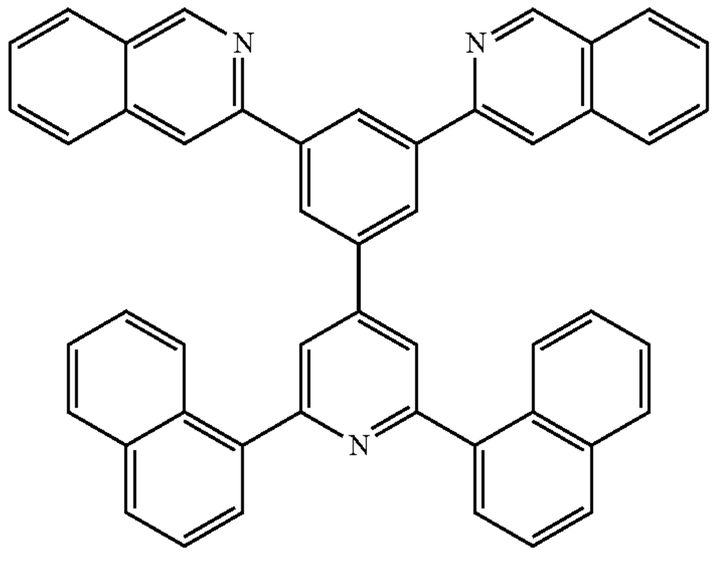

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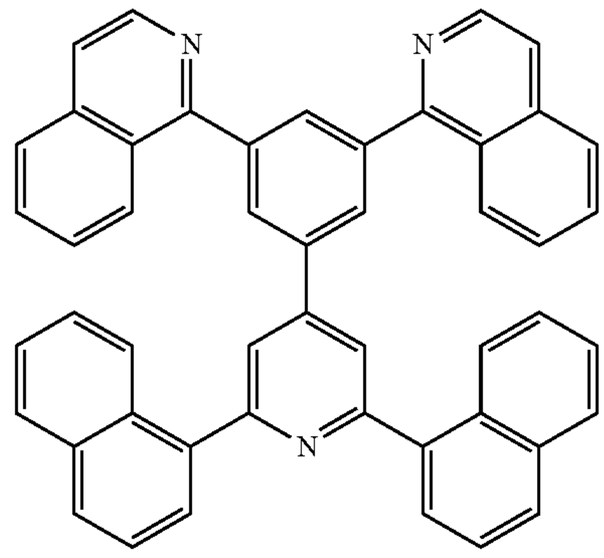

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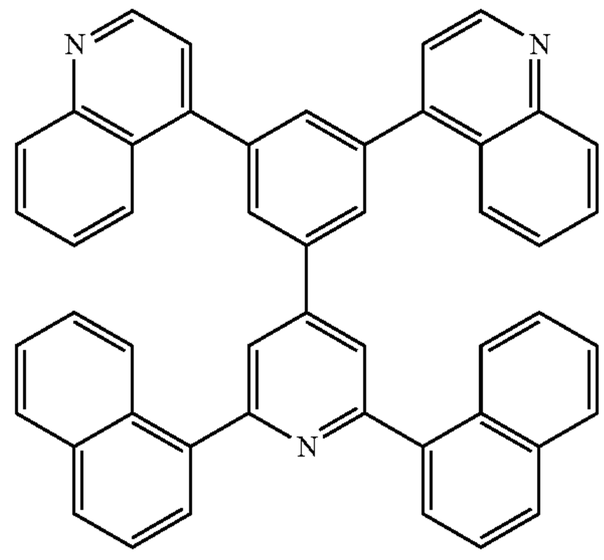

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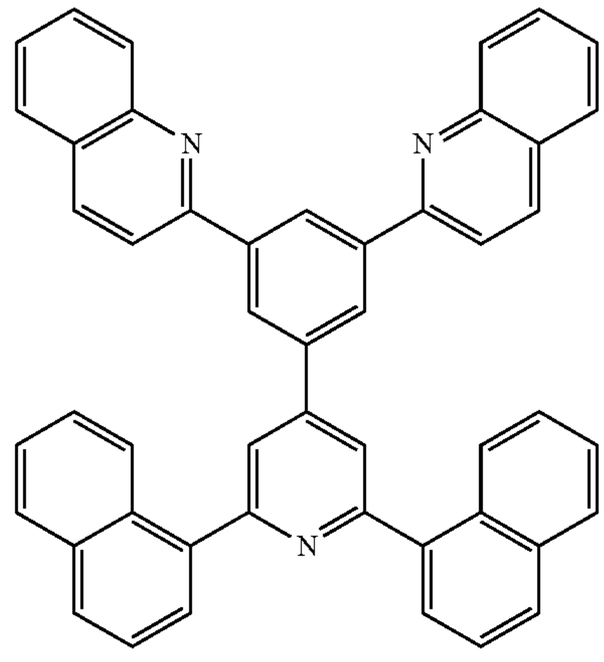

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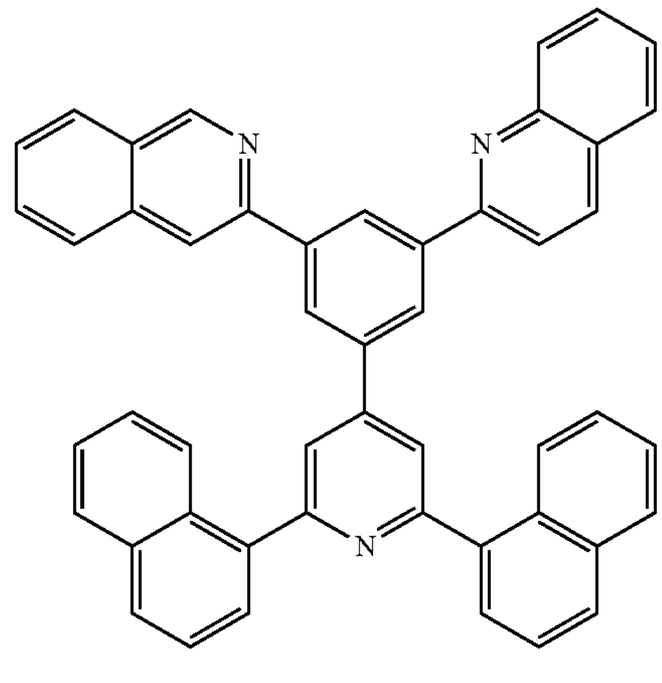

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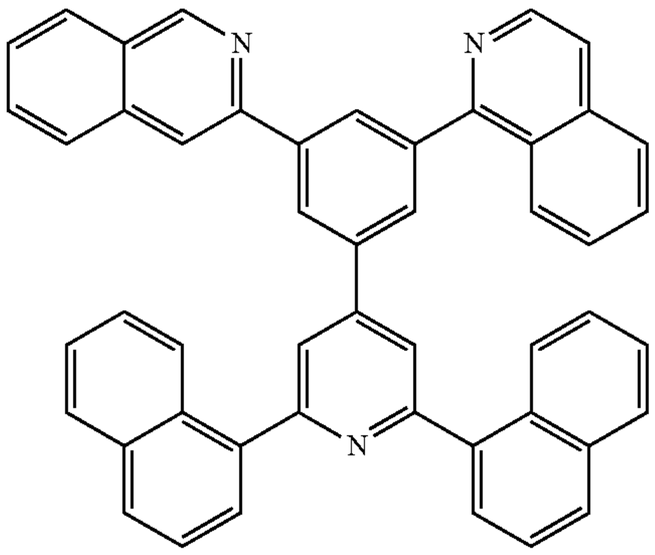

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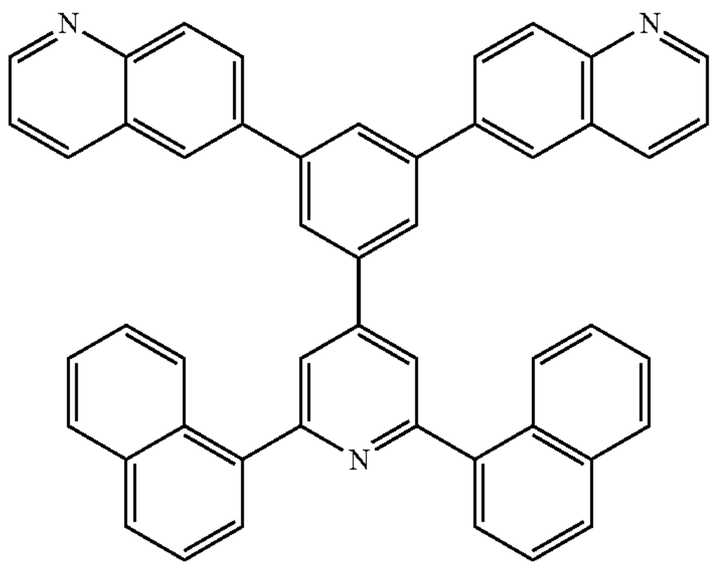

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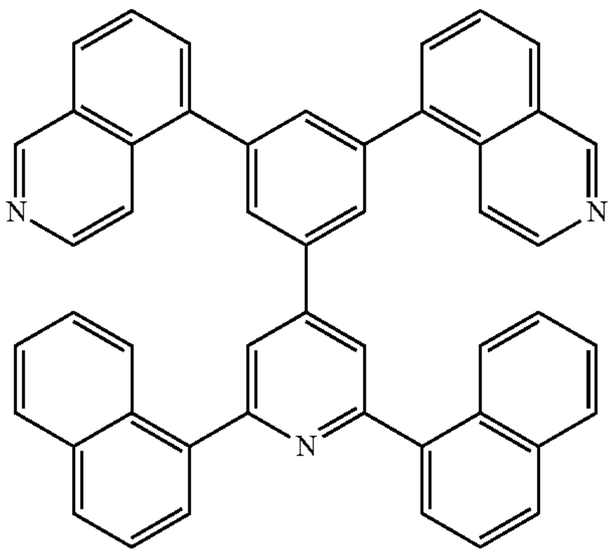

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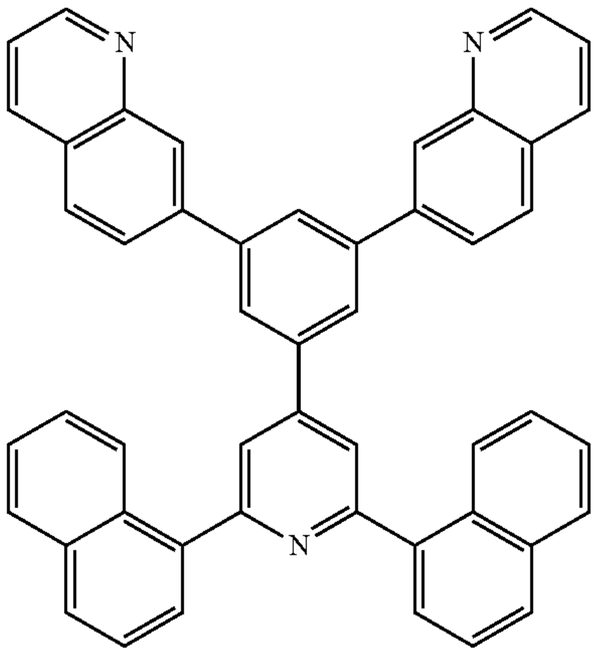

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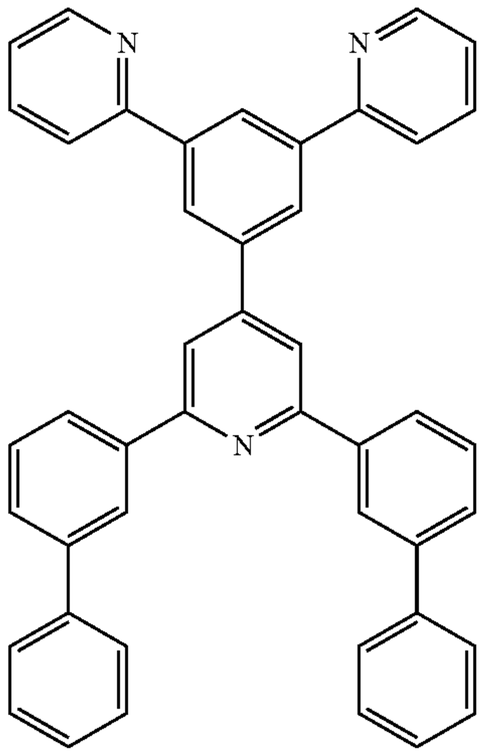

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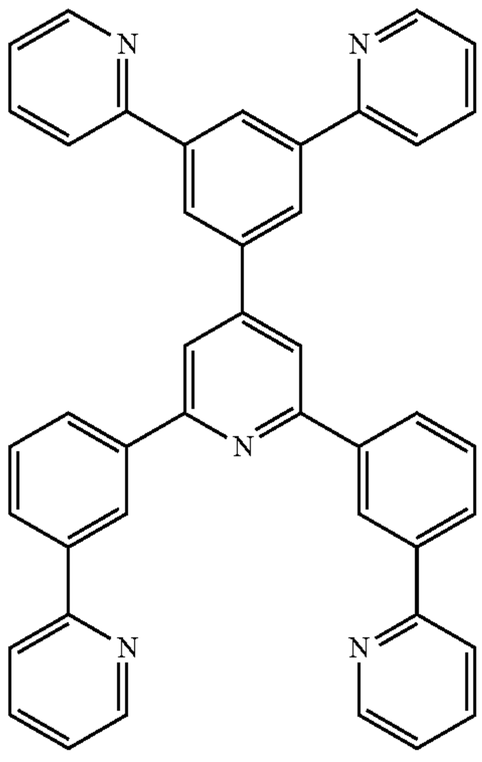

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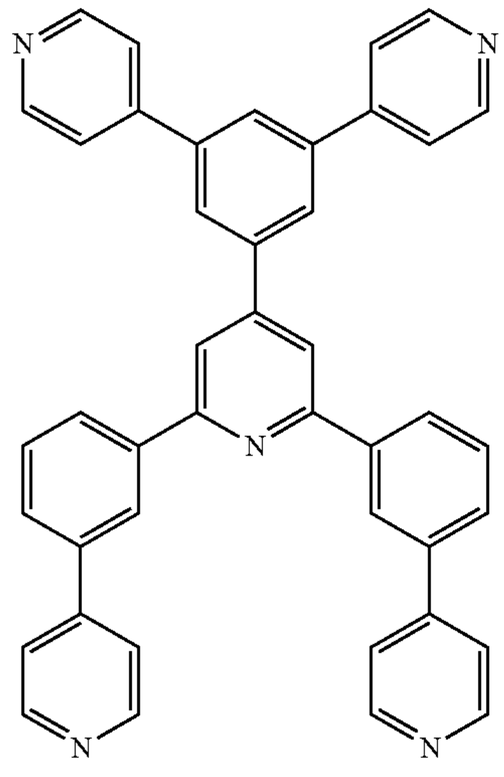

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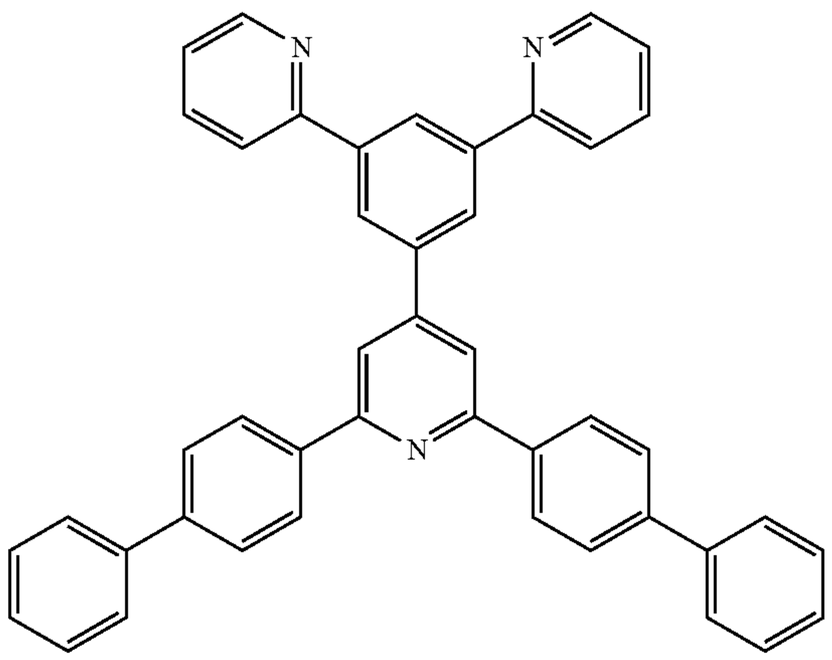

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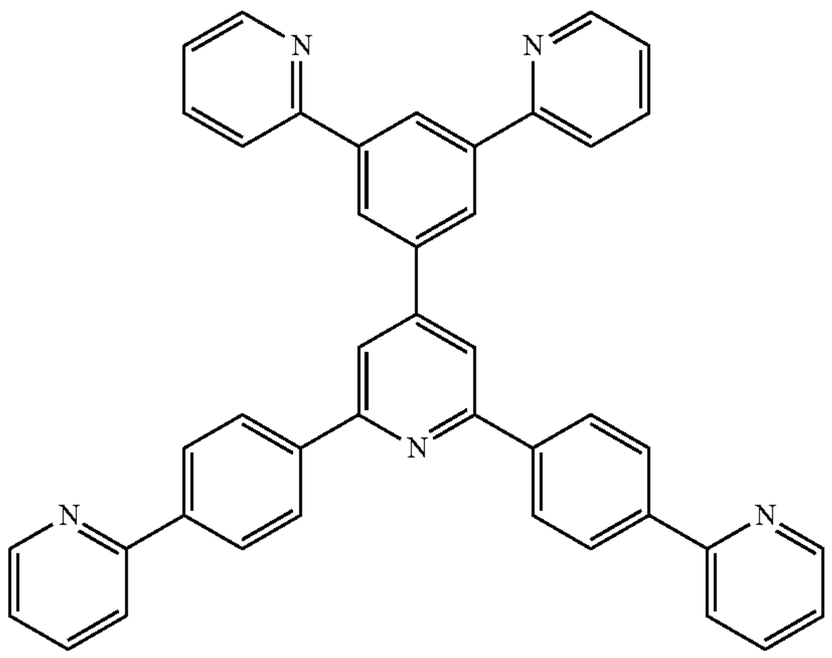

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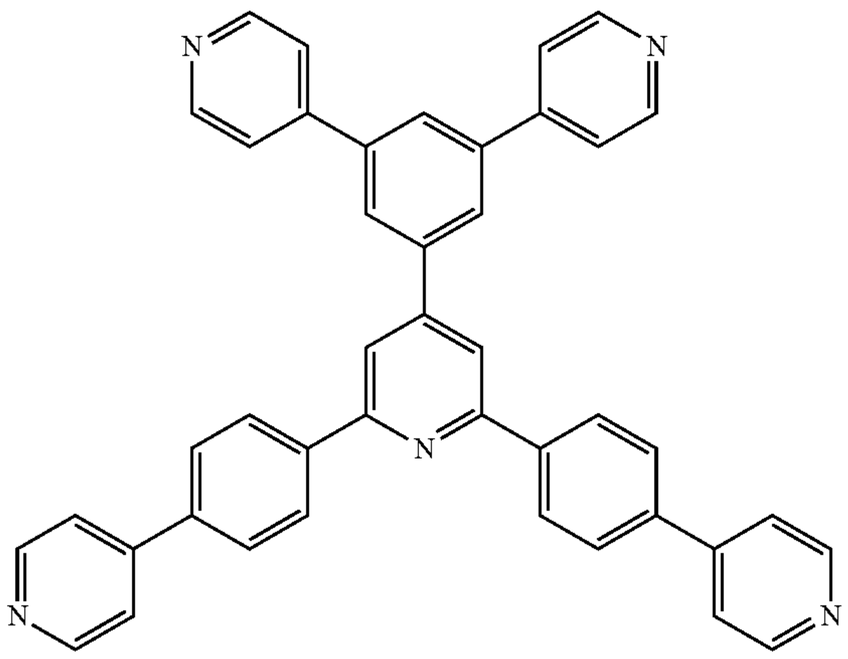

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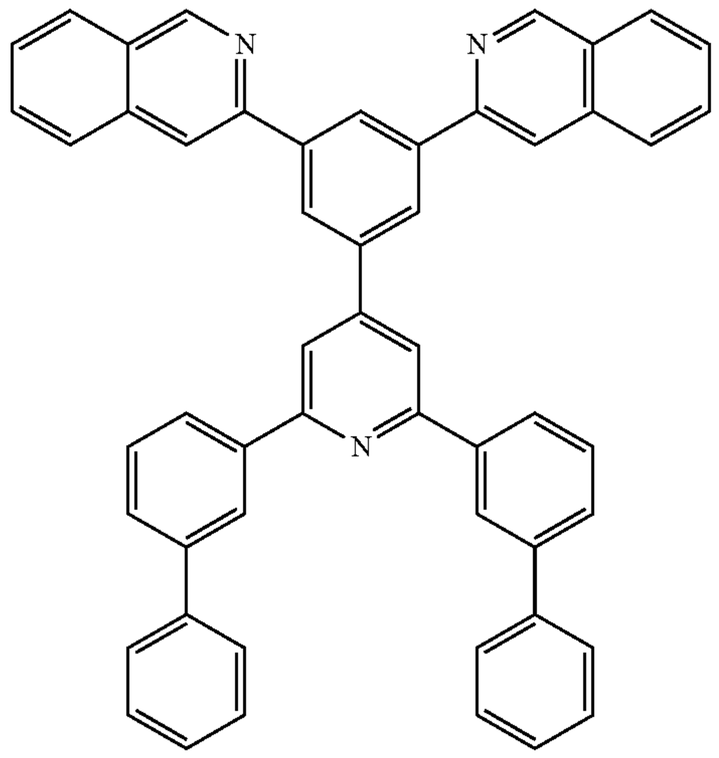

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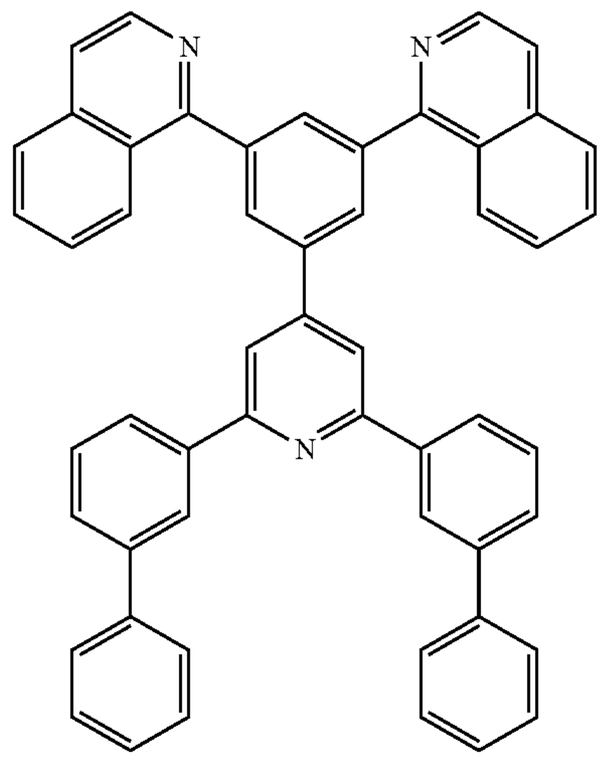

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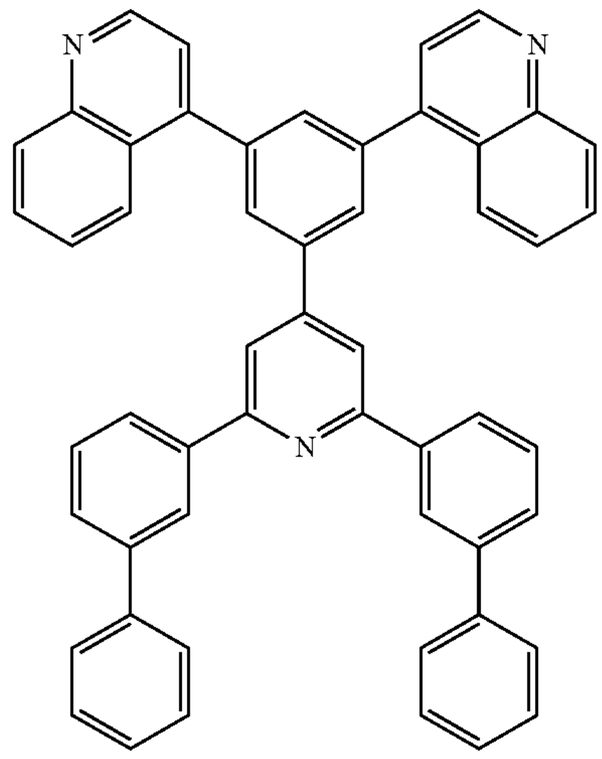

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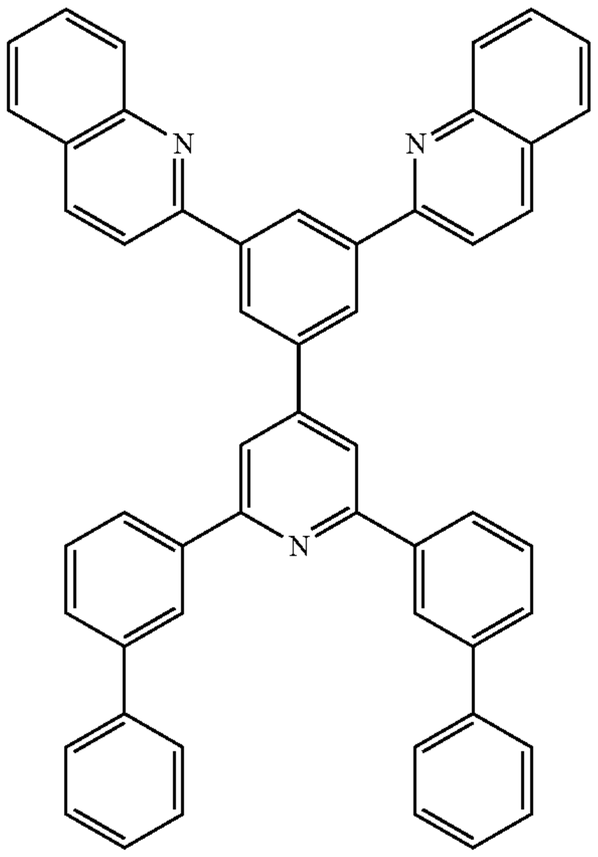

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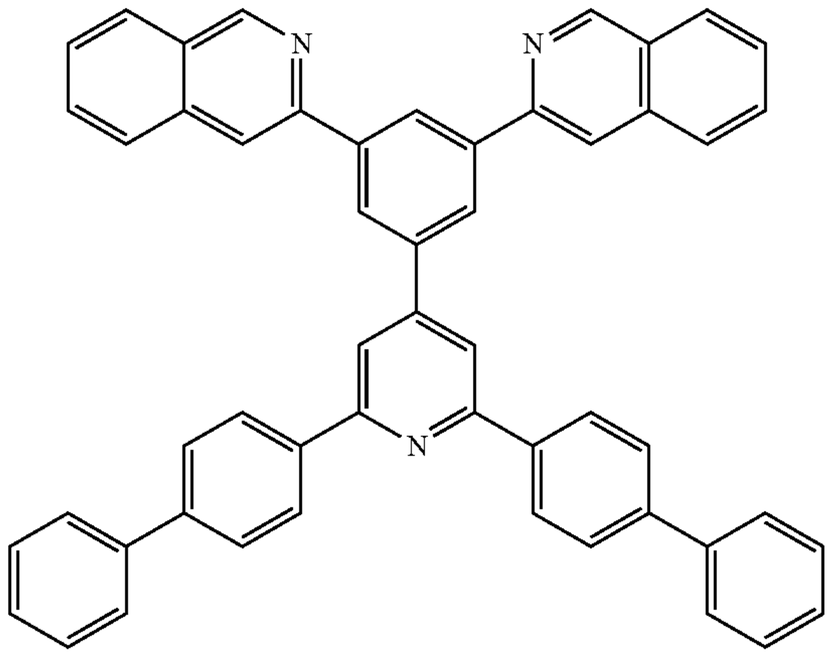

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542

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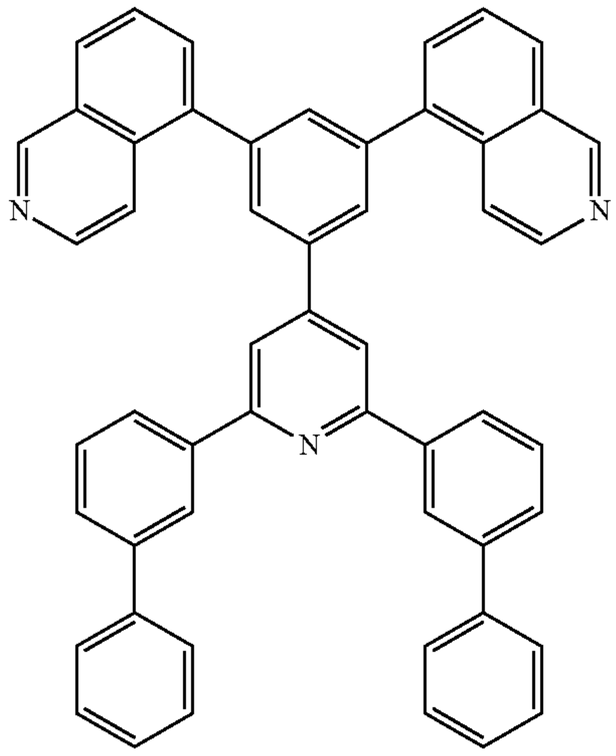

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Generally, an anthracene-based compound having a symmetrical structure and high crystallinity is known to have

low film formability. However, the first material represented by Formula 1 above has an asymmetrical structure and thus, film formability of the first material may be improved. The first material represented by Formula 1 may have a bulky substituent having greater steric hindrance than a phenyl group at the tenth carbon of anthracene, which leads to reduced association with a dopant, and thus, efficiency and lifespan of an organic light-emitting device may be improved.

The second material represented by Formula 2 may have great electron transporting ability.

Accordingly, an organic light-emitting device including the first material and the second material may have high efficiency and a long lifespan.

The organic layer **150** may further include a hole transport region **130** disposed between the first electrode **110** and the EML. The organic layer **150** may further include an electron transport region disposed between the EML and the second electrode.

The hole transport region may include at least one selected from a hole injection layer (HIL), a hole transport layer (HTL), a buffer layer, and an electron blocking layer (EBL); and the electron transport region may include at last one selected from a hole blocking layer (HBL), an electron transport layer (ETL), and an electron injection layer (EIL), but each of the hole transport region and the electron transport region is not limited thereto.

The hole transport region may include a single layer formed of a single material, a single layer formed of a plurality of different materials, or a multi-layered structure including a plurality of layers formed of a plurality of different materials.

For example, the hole transport region may have a single-layered structure formed of a plurality of different materials or a structure in which HIL/HTL, HIL/HTL/buffer layer, HIL/buffer layer, HTL/buffer layer, or HIL/HTL/EBL are sequentially layered on the first electrode **110**, but it is not limited thereto.

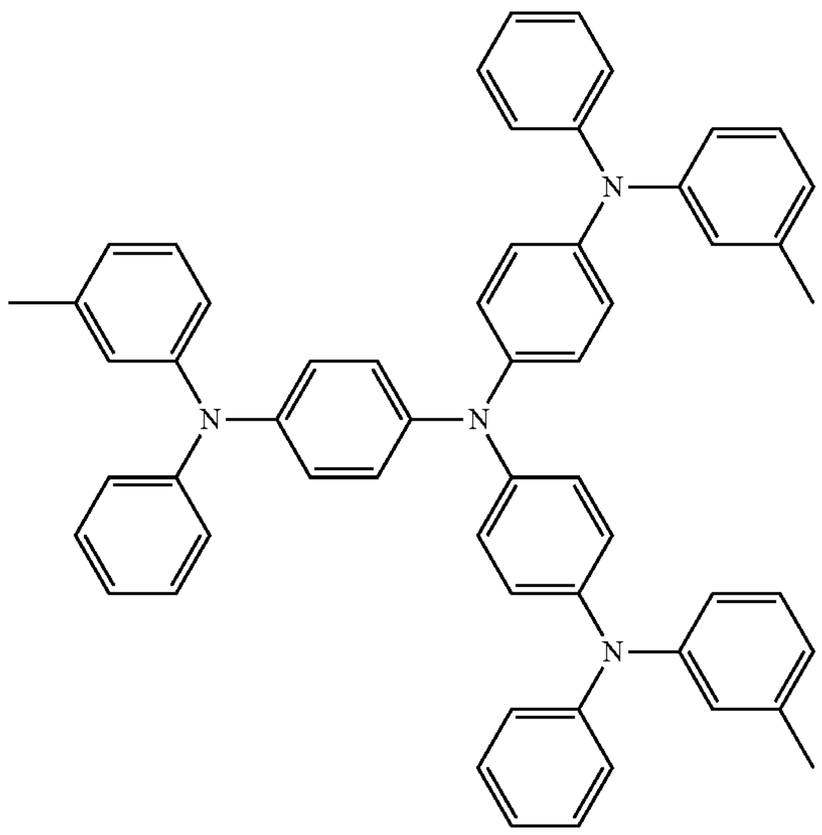
When the hole transport region includes the HIL, the HIL may be formed on the first electrode **110** by using (utilizing) various suitable methods, such as vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, inkjet printing, laser printing, or laser-induced thermal imaging (LITI).

When the HIL is formed by using (utilizing) vacuum deposition, vacuum deposition conditions may vary according to the compound that is used (utilized) to form the HIL and the desired structure of the HIL to be formed. For example, vacuum deposition may be performed at a temperature of about 100° C. to about 500° C., a pressure of about 10^{-8} torr to about 10^{-3} torr, and a deposition rate of about 0.01 to about 100 Å/sec, depending on the s

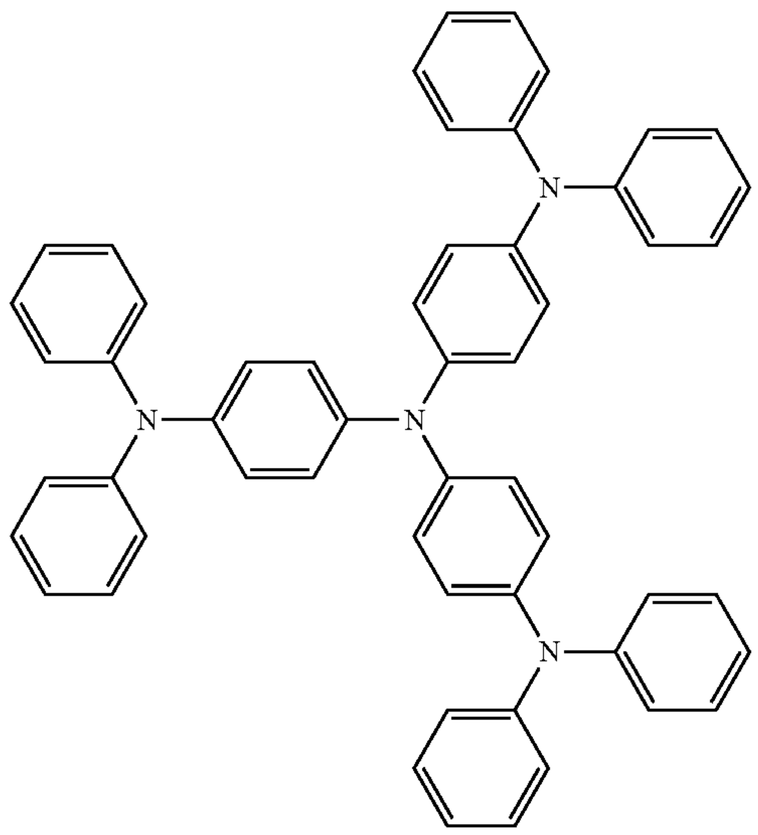
When the HIL is formed by using (utilizing) spin coating, the coating conditions may vary according to the compound that is used (utilized) to form the HIL and the desired structure of the HIL to be formed. For example, the coating rate may be in the range of about 2000 rpm to about 5000 rpm, and a temperature at which a heat treatment is performed may be in the range of about 80° C. to about 200° C.

When the hole transport region includes the HTL, the HTL may be formed on the first electrode **110** or on the HIL by using (utilizing) various suitable methods, such as vacuum deposition, spin coating, casting, LB deposition, inkjet printing, laser printing, or LITI. When the HTL is formed by vacuum deposition or spin coating, the vacuum deposition conditions and coating conditions may be the same as the vacuum deposition conditions and the coating conditions of the HIL.

The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, α-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine(4,4',4"-tris(N-carbazolyl)triphenylamine) (TCTA), polyaniline/dodecylbenzenesulfonic acid (Pani/DBSA), Poly(3,4-ethylenedioxythiophene)/Poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (pani/CSA), or (polyaniline)/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201 below, and a compound represented by Formula 202 below.



m-MTDATA



TDATA

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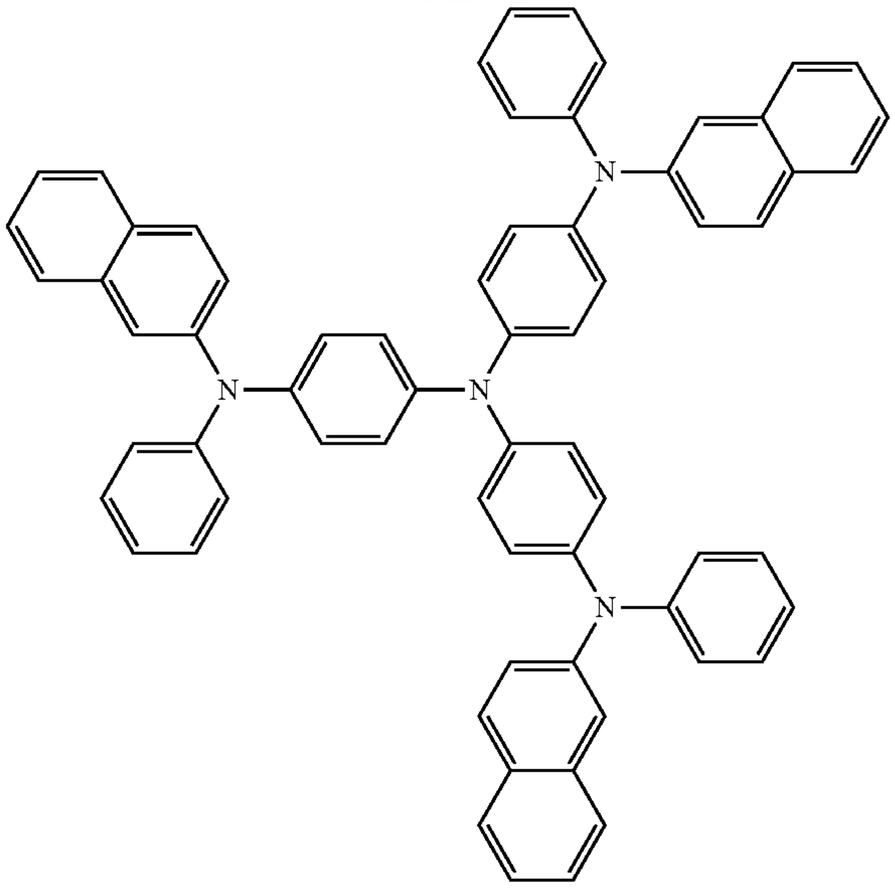
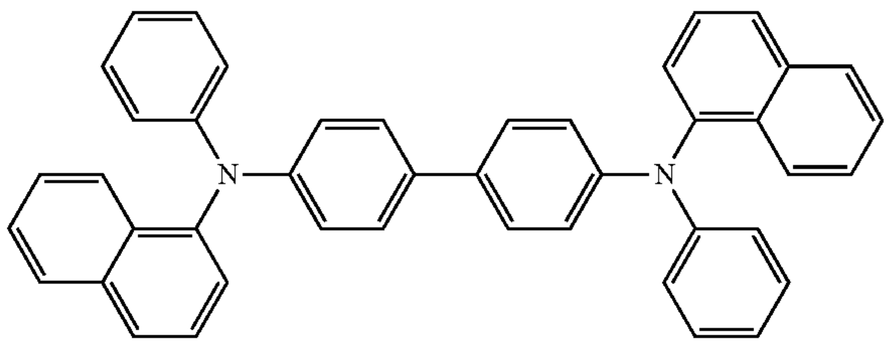
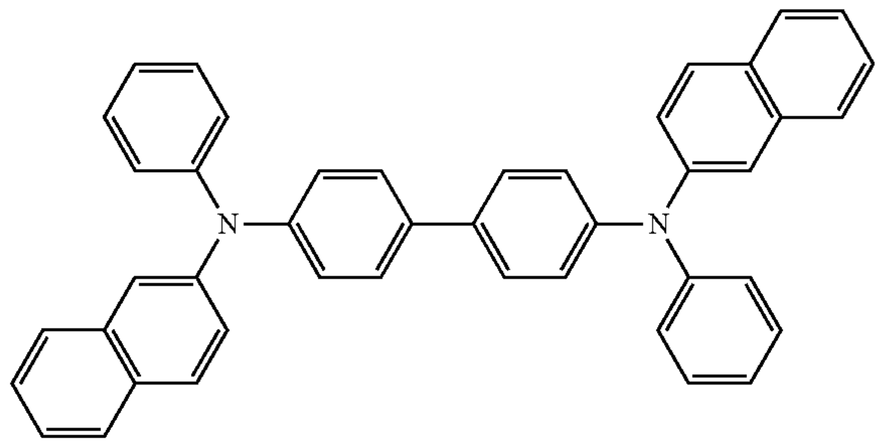


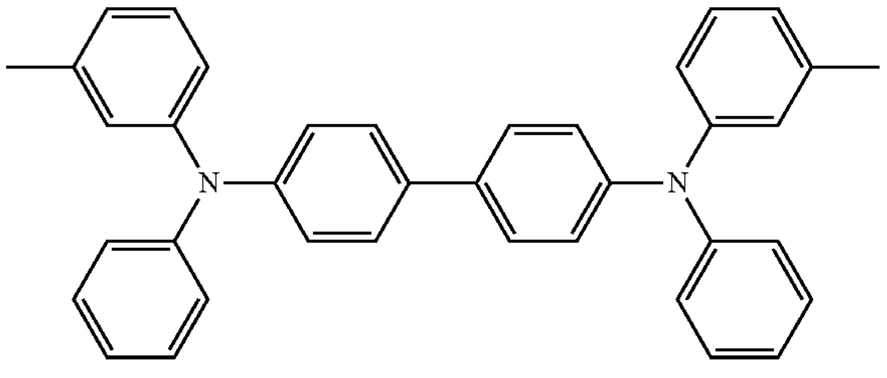
2-TNATA



NPB



β-NPB



TPD

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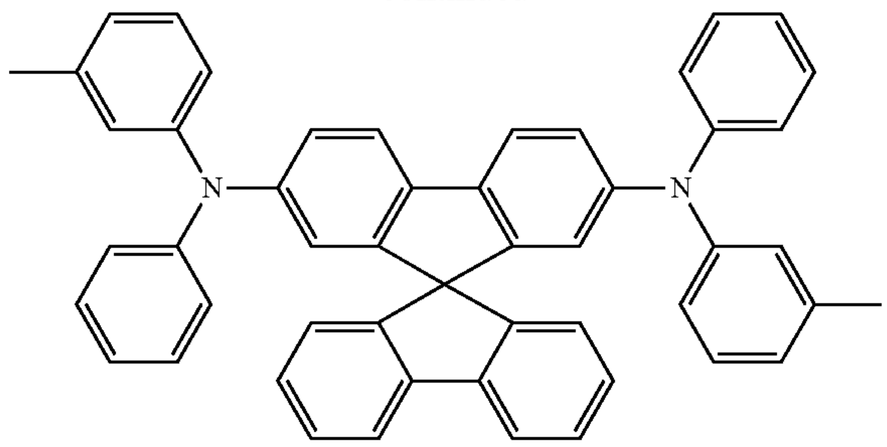
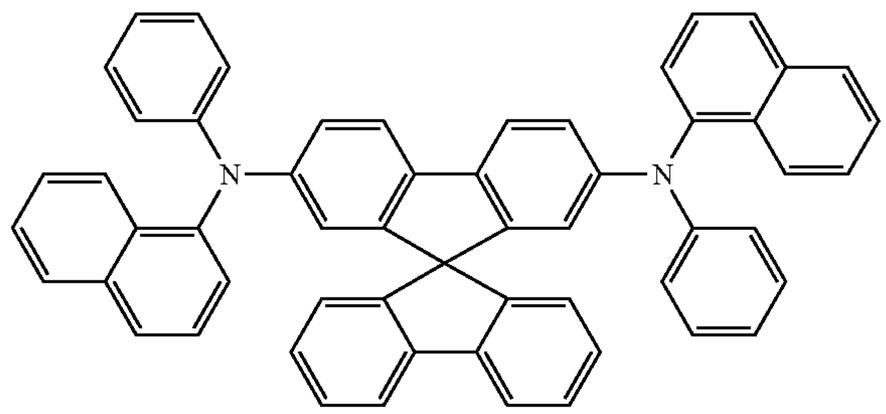
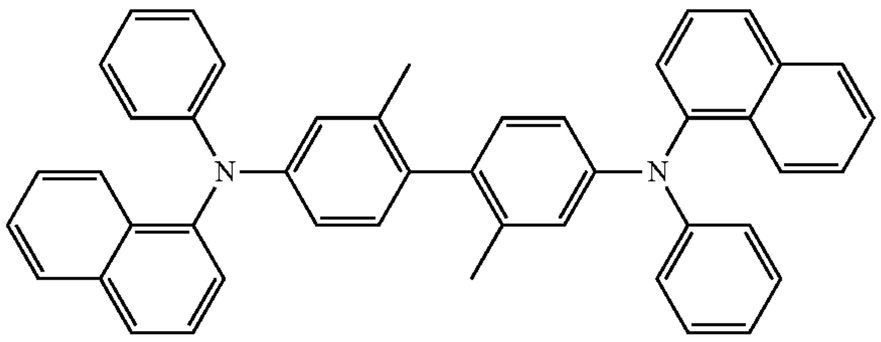


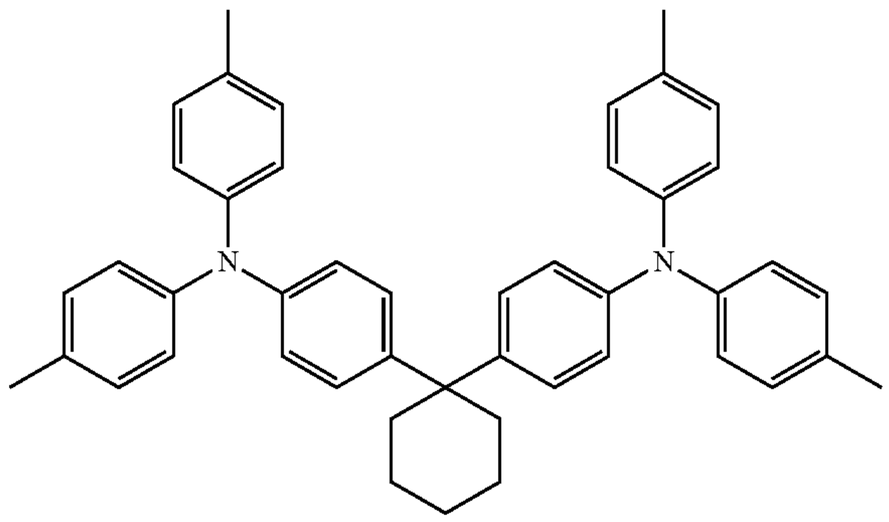
Spiro-TPD



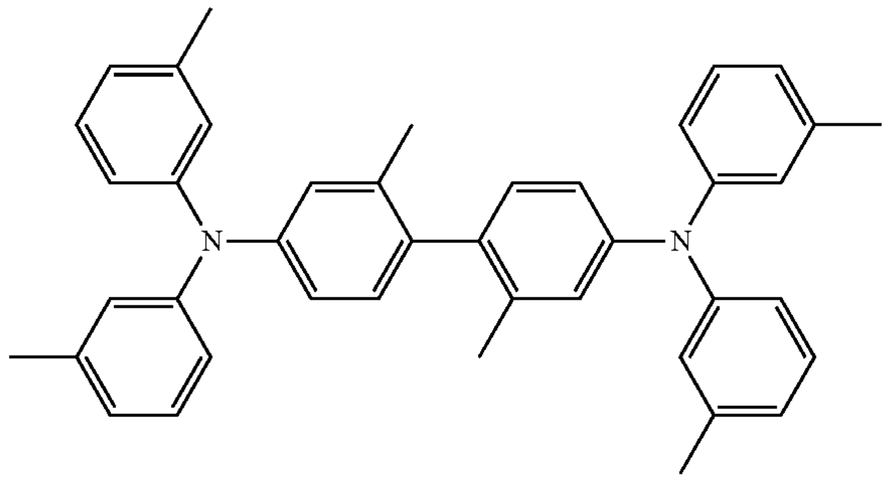
Spiro-NPB



α-NPB

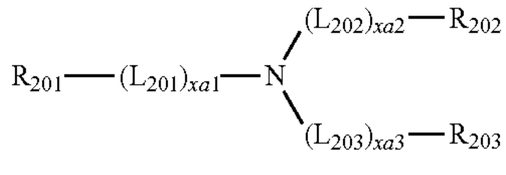


TAPC



HMTPD

Formula 201



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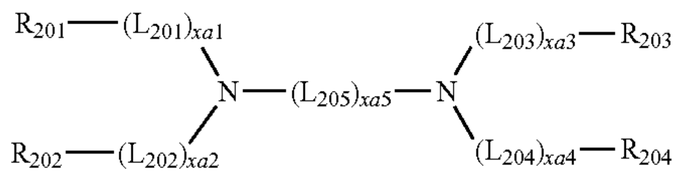
Formula 202



In Formulae 201 and 202,

L_{201} to L_{205} may be each independently selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene, a substituted or unsubstituted C_3-C_{10} heterocycloalkylene, a substituted or unsubstituted C_3-C_{10} cycloalkenylene, a substituted or unsubstituted C_3-C_{10} heterocycloalkenylene, a substituted or unsubstituted C_6-C_{60} arylene, a substituted or unsubstituted C_2-C_{60} heteroarylene, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic hetero-condensed polycyclic group;

at least one substituent of the substituted C_3-C_{10} cycloalkylene, substituted C_3-C_{10} heterocycloalkylene, substituted C_3-C_{10} cycloalkenylene, substituted C_3-C_{10} heterocycloalkenylene, substituted C_6-C_{60} arylene, substituted C_2-C_{60} heteroarylene, substituted divalent non-aromatic condensed polycyclic group, and substituted divalent non-aromatic hetero-condensed polycyclic group may be selected from:

deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, —$N(Q_{201})(Q_{202})$, —$Si(Q_{203})(Q_{204})(Q_{205})$, and —$B(Q_{206})(Q_{207})$;

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group;

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{50} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a non-aromatic condensed polycyclic group, —$N(Q_{231})(Q_{232})$, —$Si(Q_{233})(Q_{234})(Q_{235})$, and —$B(Q_{236})(Q_{237})$;

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{50} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group; and

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, —$N(Q_{241})(Q_{242})$, —$Si(Q_{243})(Q_{244})(Q_{245})$, and —$B(Q_{246})(Q_{247})$; wherein,

Q_{201} to Q_{207}, Q_{211} to Q_{217}, Q_{221} to Q_{227}, Q_{231} to Q_{237}, and Q_{241} to Q_{247} may be each independently selected from:

hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt

thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group;

C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group; and

a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{50} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group.

For example, in Formulae 201 and 202,

L_{201} to L_{205} may be each independently selected from:

a phenylene group, a naphthylenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

a phenylene group, a naphthylenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

xa1 to xa4 may be each independently 0, 1, or 2;

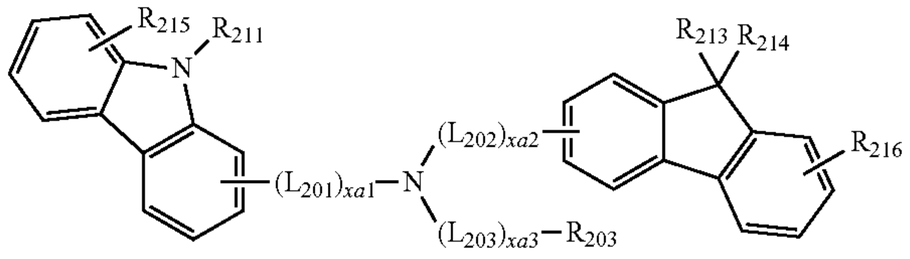
xa5 may be 1, 2, or 3;

R_{201} to R_{205} may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group.

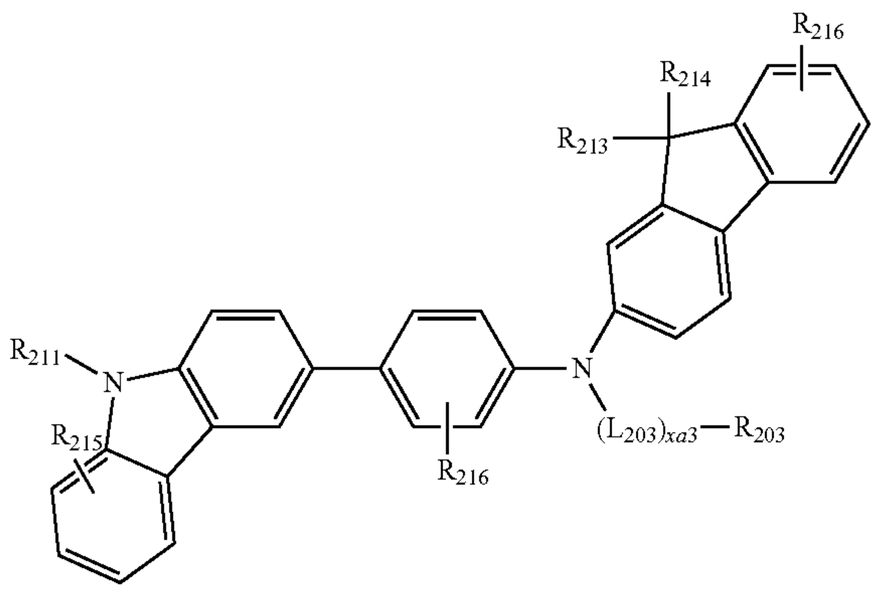
The compound represented by Formula 201 above may be represented by Formula 201A below:

Formula 201A



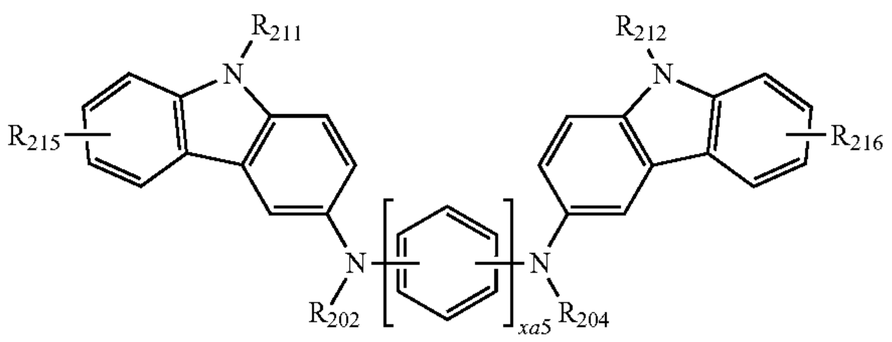
For example, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but it is not limited thereto:

Formula 201A-1



The compound represented by Formula 202 above may be represented by Formula 202A below, but it is not limited thereto:

Formula 202A



In Formulae 201A, 201A-1 and 202A, descriptions of L_{201} to L_{203}; xa1 to xa3, xa5, and R_{202} to R_{204} may be the same as the descriptions herein; R_{211} and R_{212} may be understood by referring to R_{203}; and R_{213} to R_{216} may be each independently selected from hydrogen, deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, and a non-aromatic condensed polycyclic group.

For example, in Formulae 201A, 201A-1, and 202A above,

L_{201} to L_{203} may be each independently selected from a phenylene group, a naphthylenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group; and

a phenylene group, a naphthylenylene group, a fluorenylene group, a spiro-fluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a pyrenylene group, a chrysenylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a quinolinylene group, an isoquinolinylene group, a quinoxalinylene group, a quinazolinylene group, a carbazolylene group, and a triazinylene group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

xa1 to xa3 may be each independently 0 or 1;

R_{203}, R_{211} and R_{212} may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

R_{213} and R_{214} may be each independently selected from a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

R_{215} and R_{216} may be each independently selected from a hydrogen, a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid, group or a salt thereof,

a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group;

a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

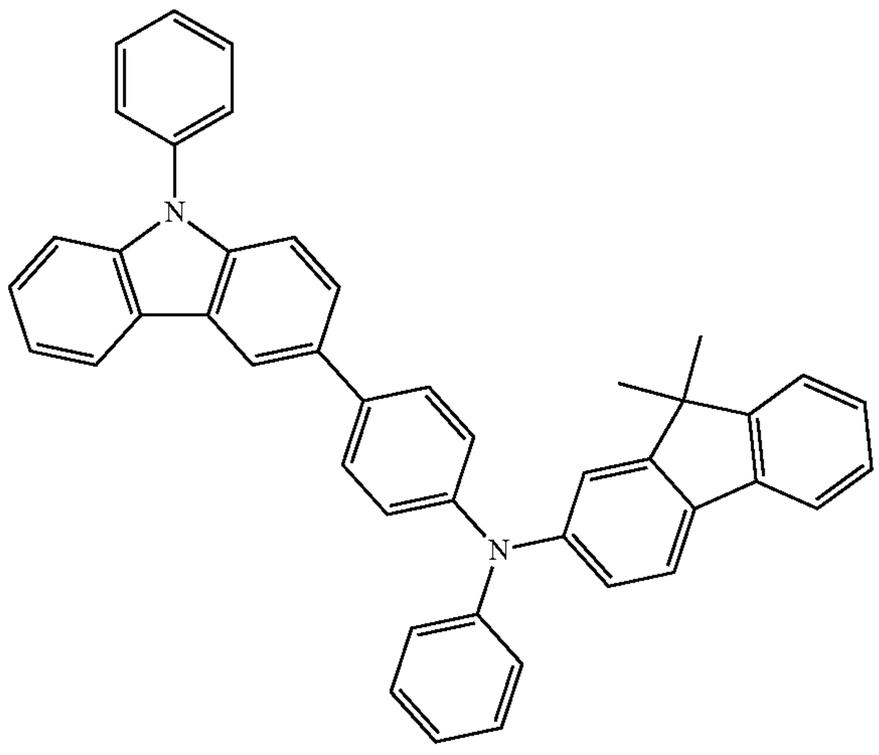
a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

xa5 is 1 or 2.

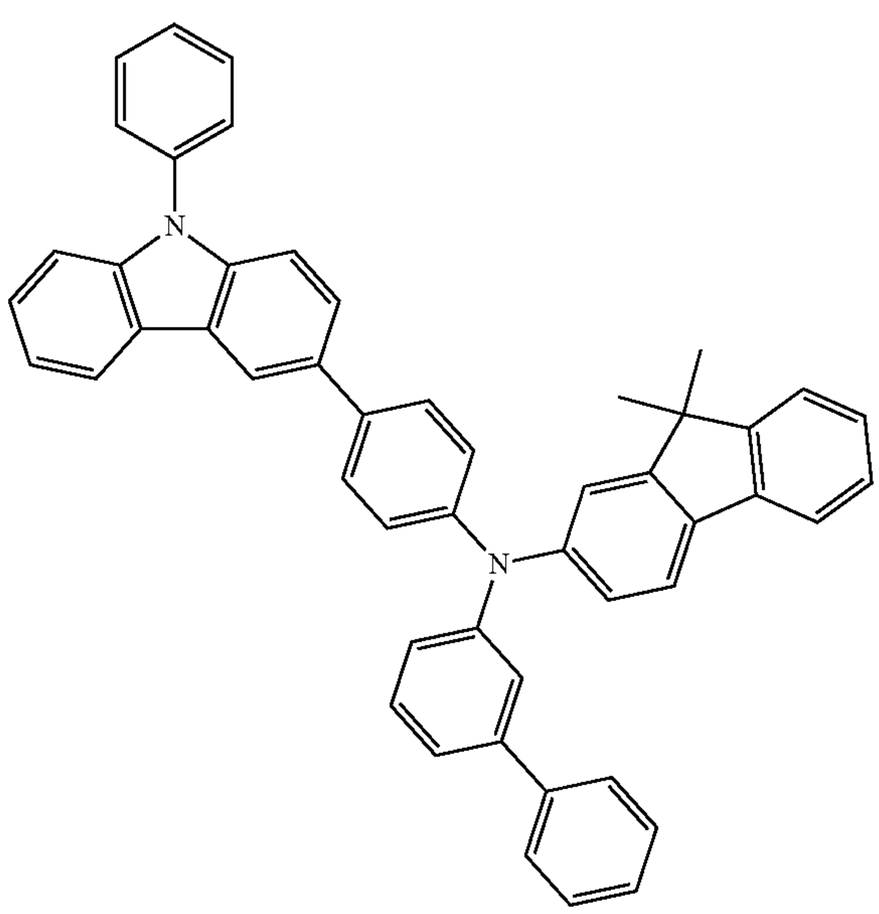
In Formulae 201A and 201A-1, R_{213} and R_{214} may bind to each other to form a saturated ring or an unsaturated ring.

The compound represented by Formula 201 above and the compound represented by Formula 202 above may include Compounds HT1 to HT20, but they are not limited thereto.

HT1



HT2



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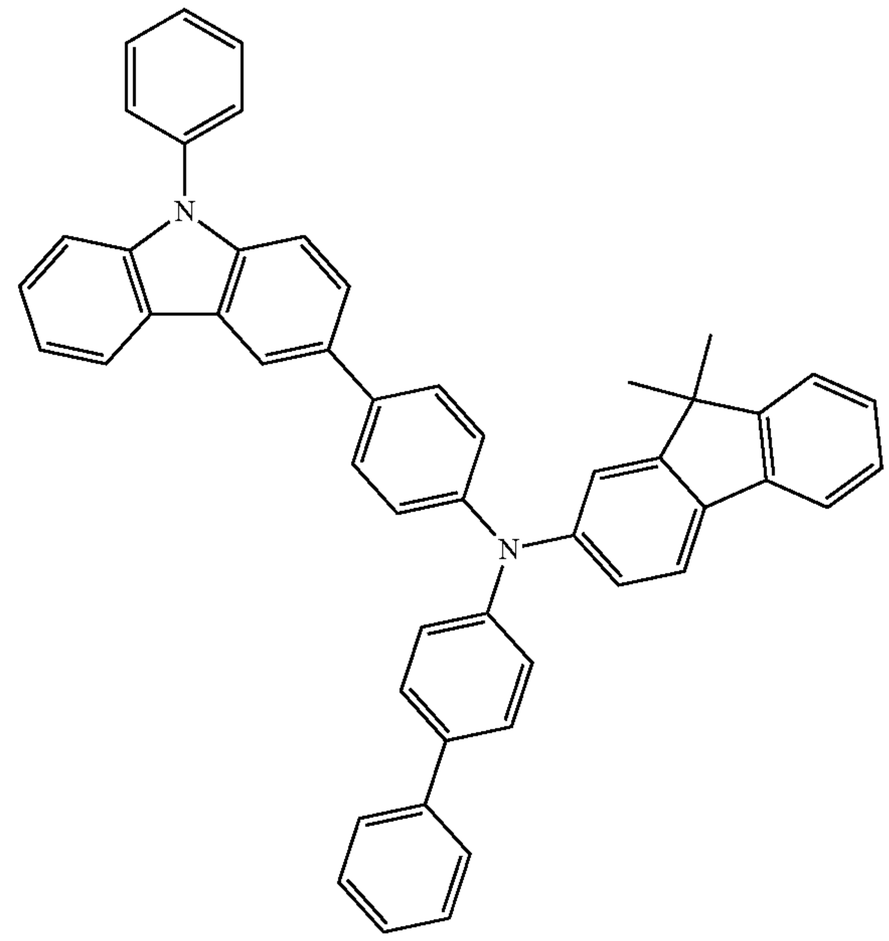
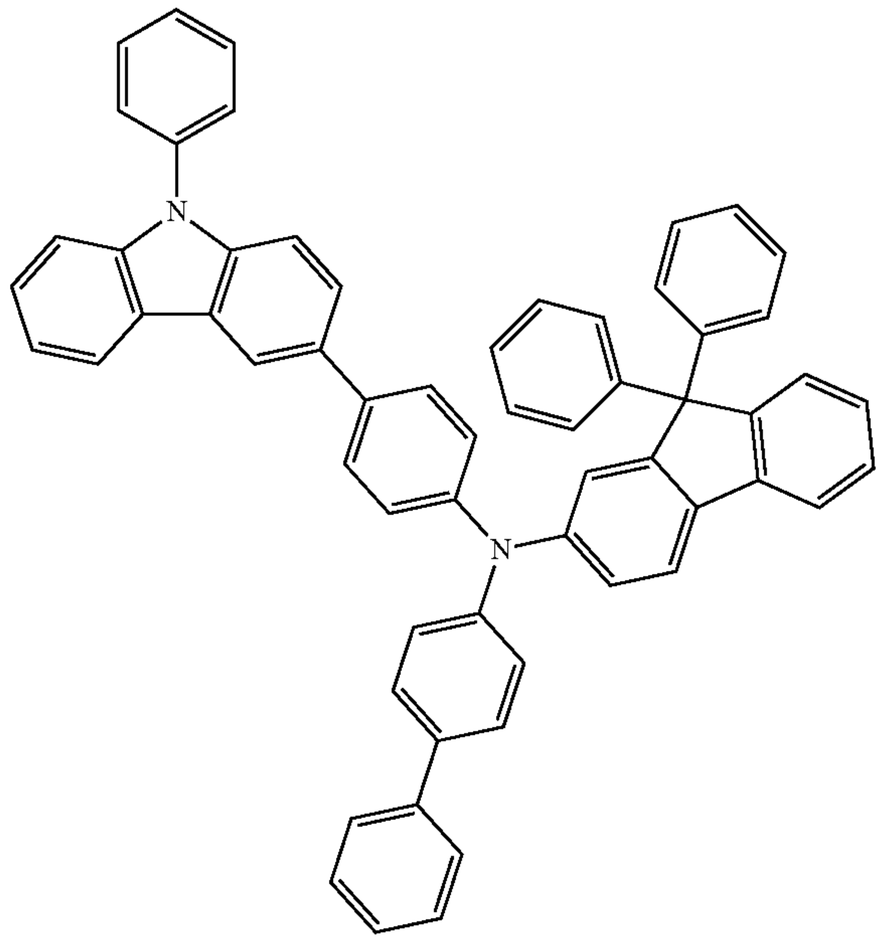
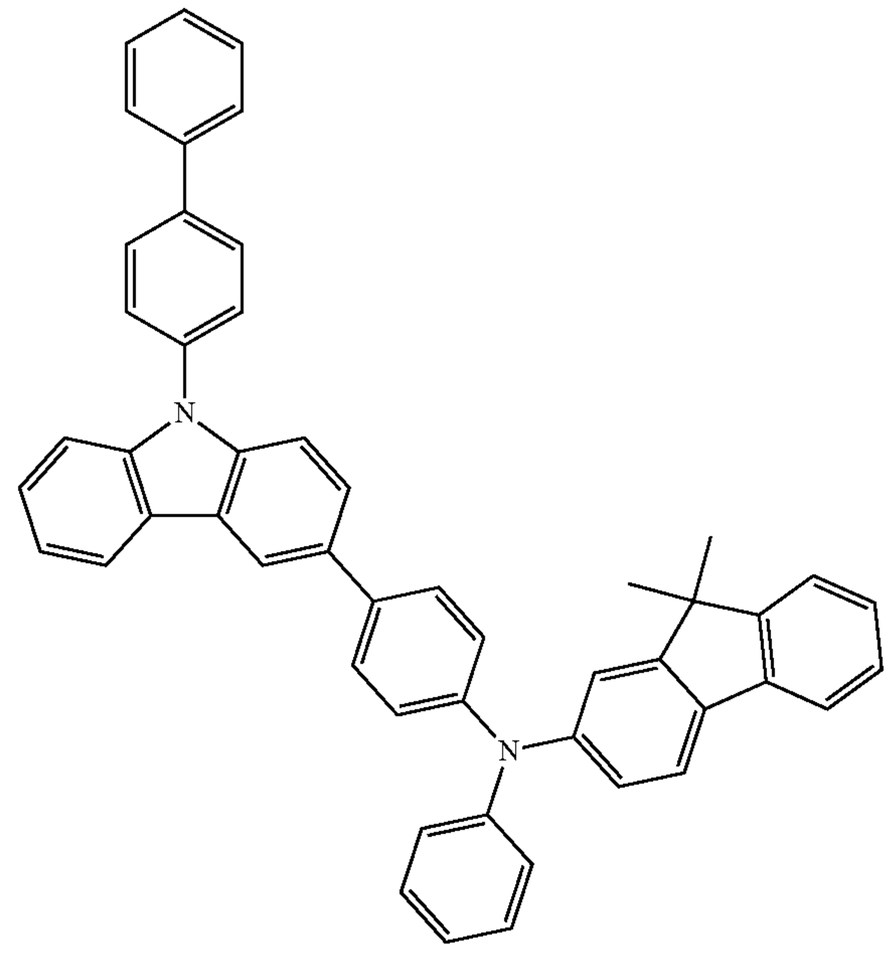
HT3



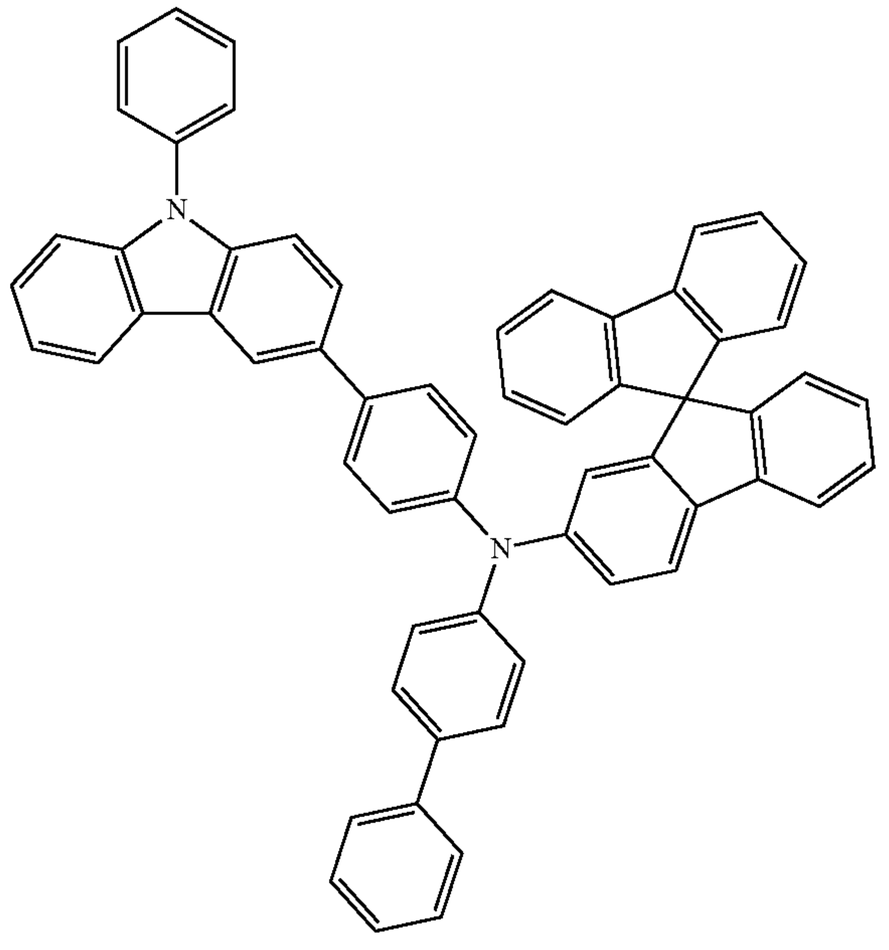
HT5



HT4



HT6



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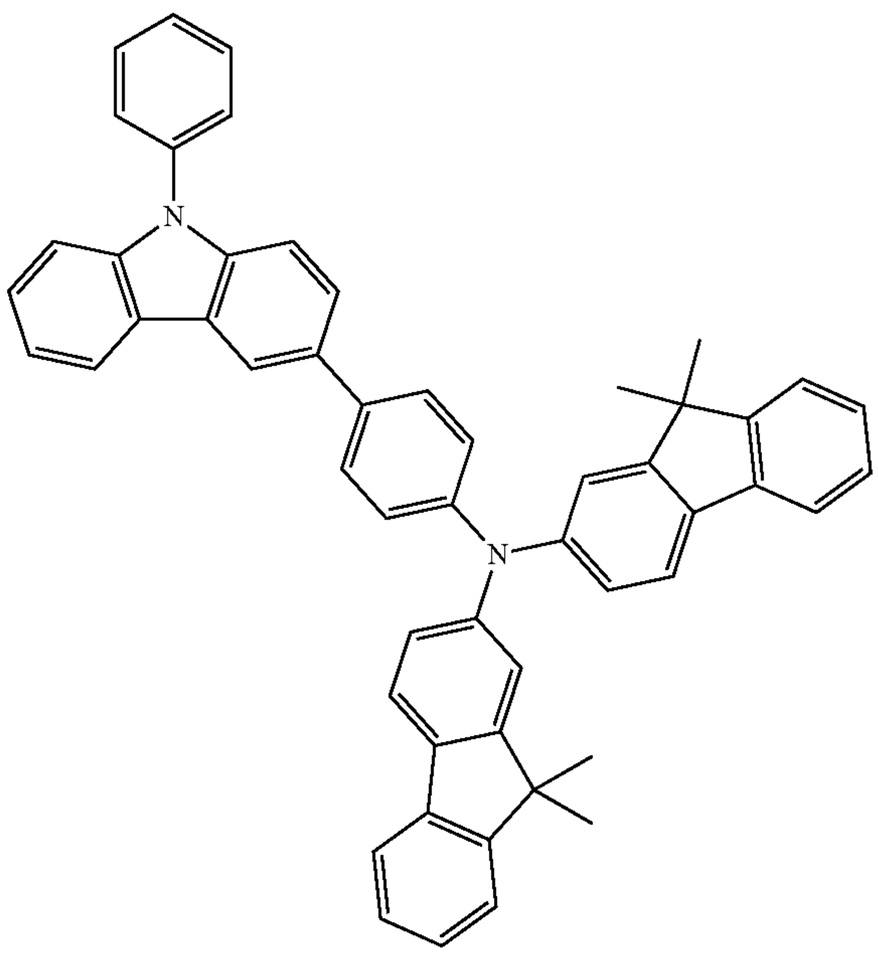
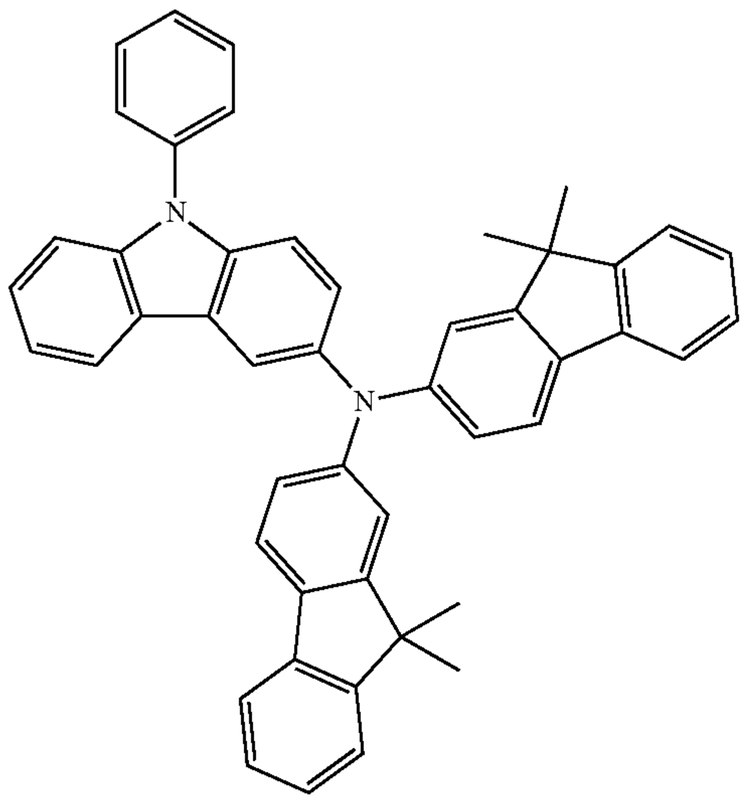
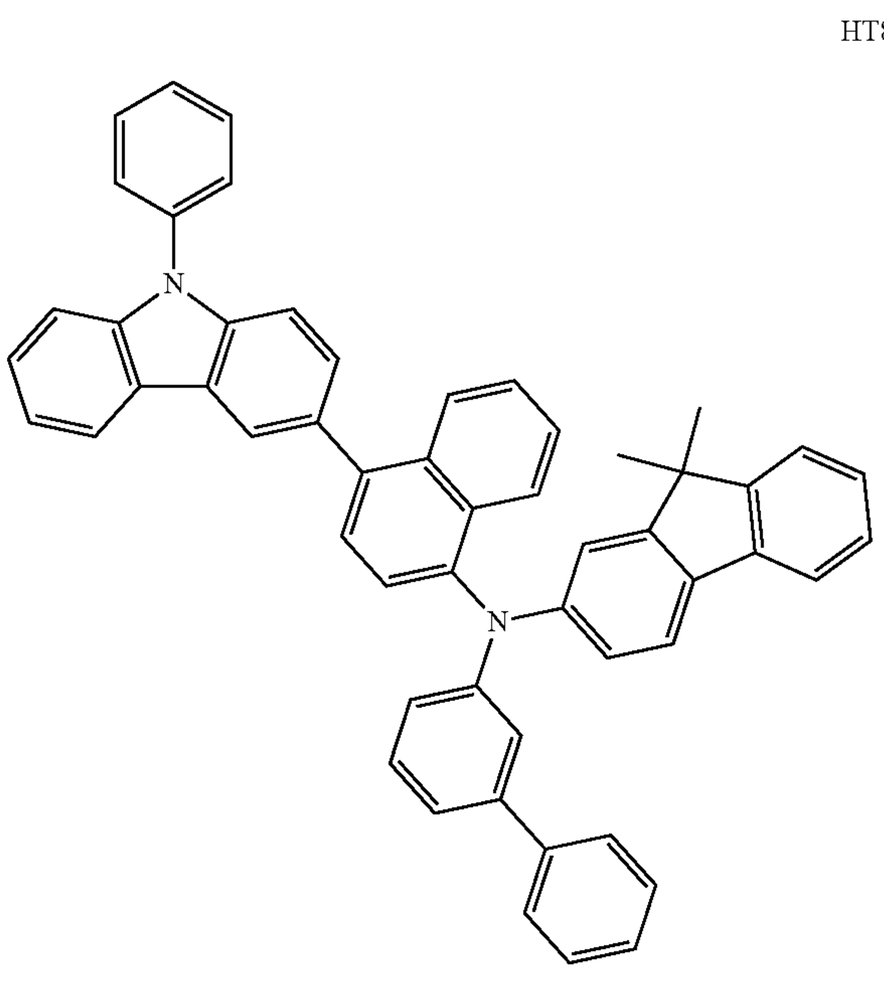
HT7



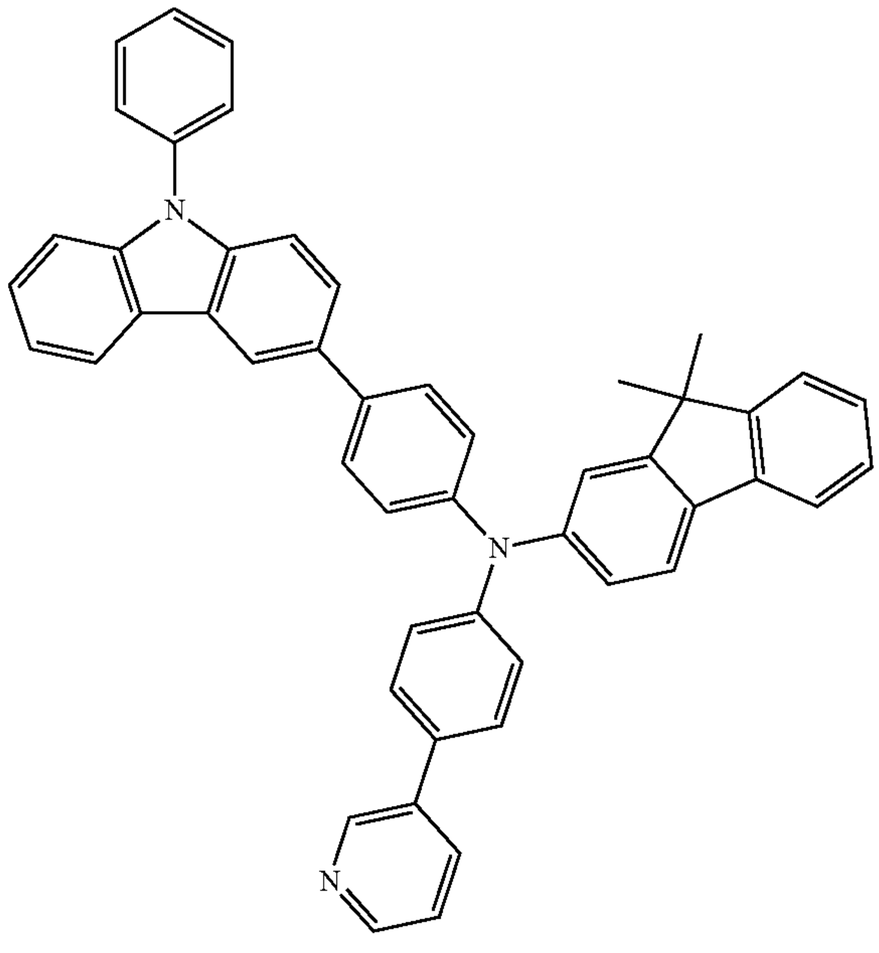
HT9



HT8



HT10



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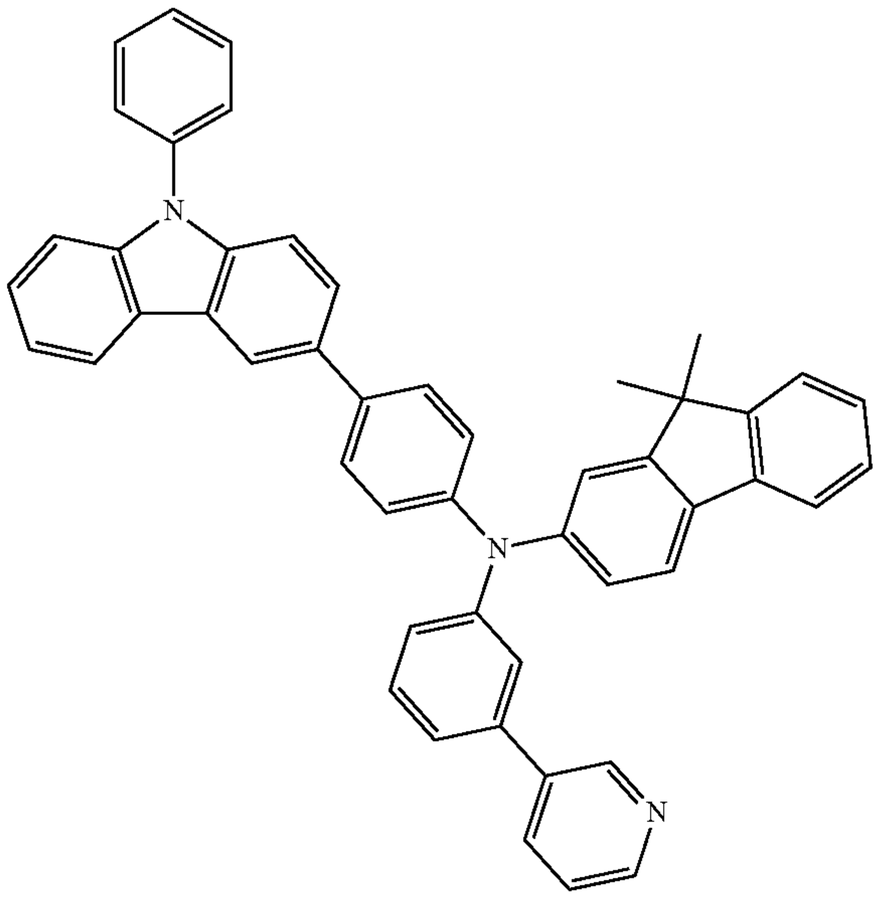
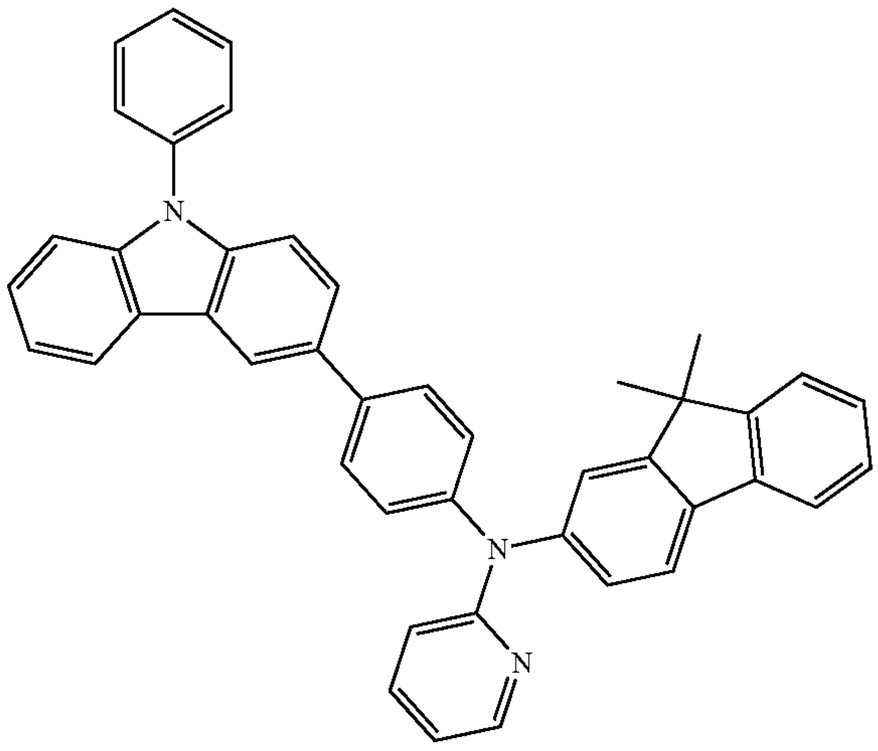
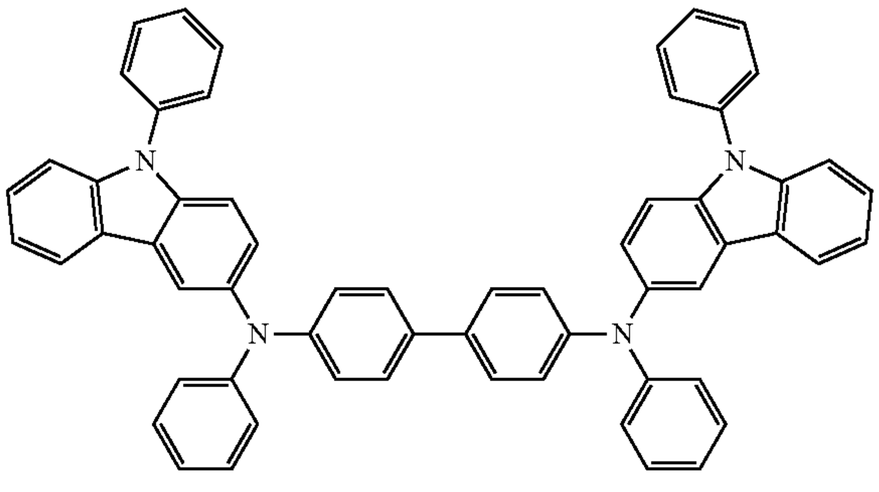
HT11



HT12



HT13



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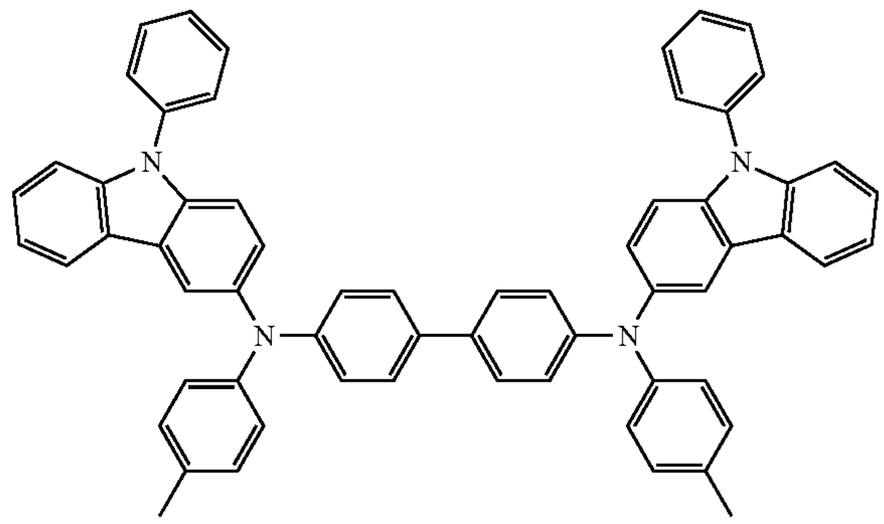
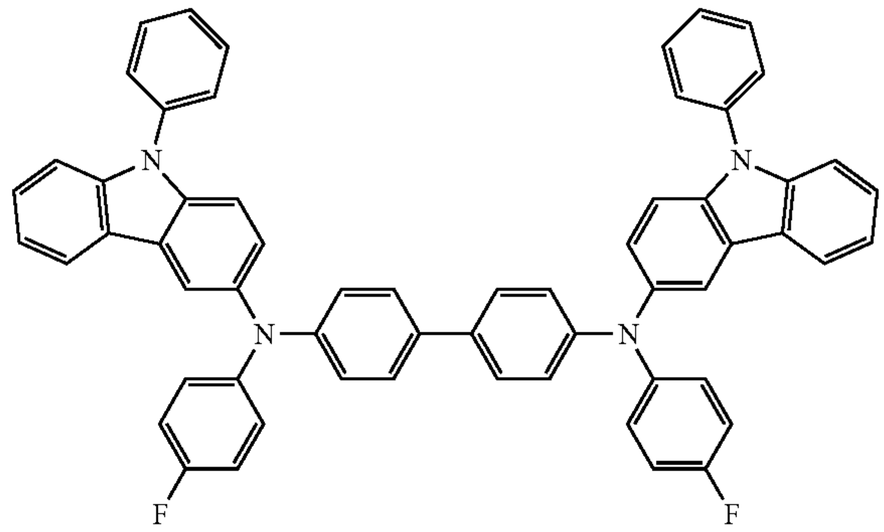
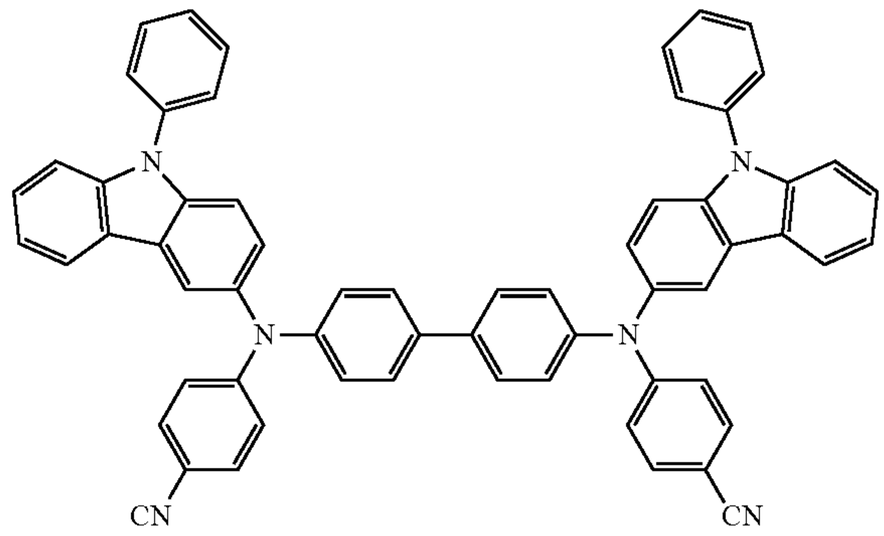
HT14



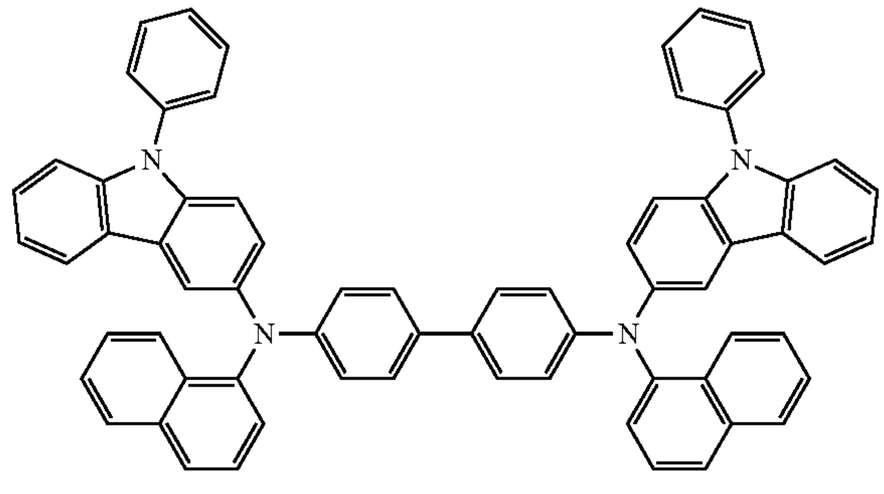
HT15



HT16



HT17



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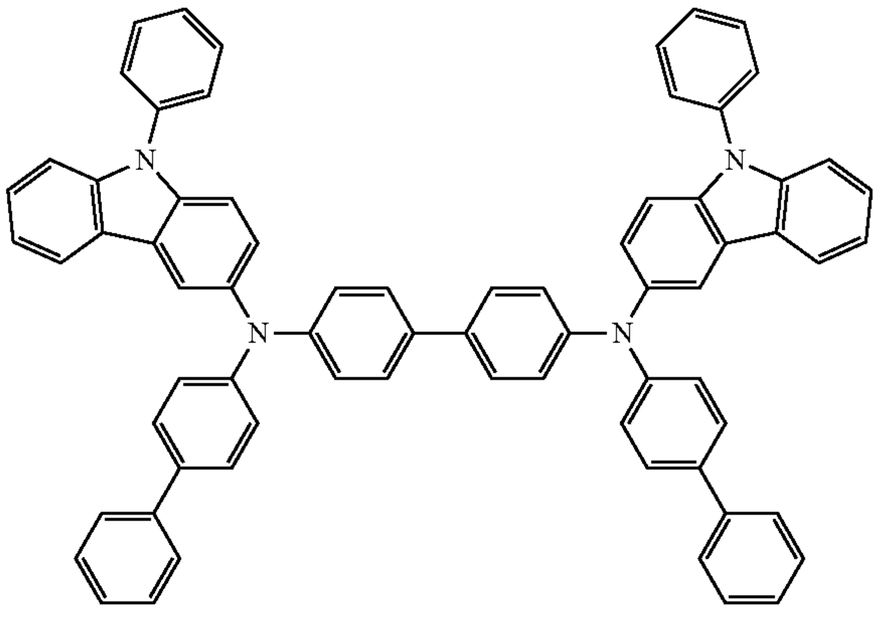
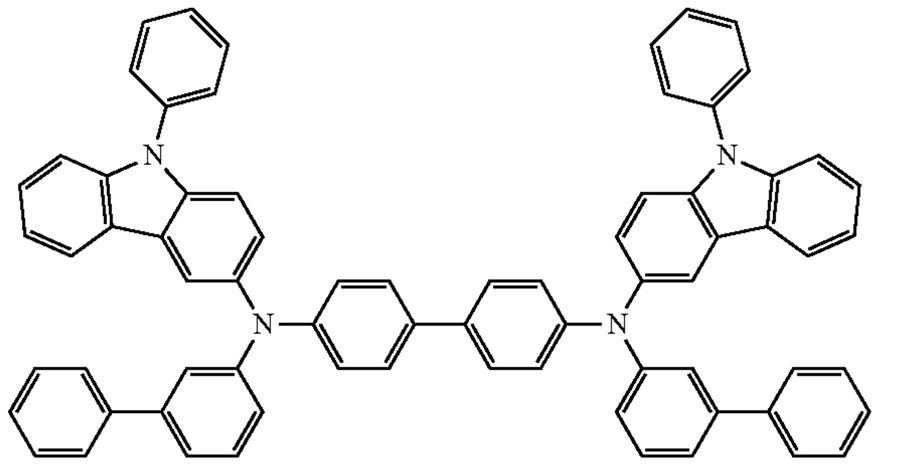
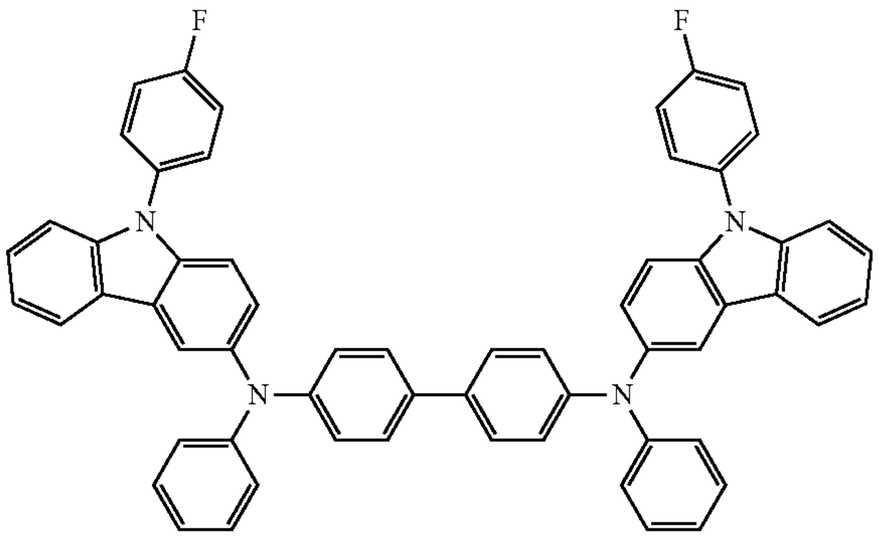
HT18



HT19



HT20

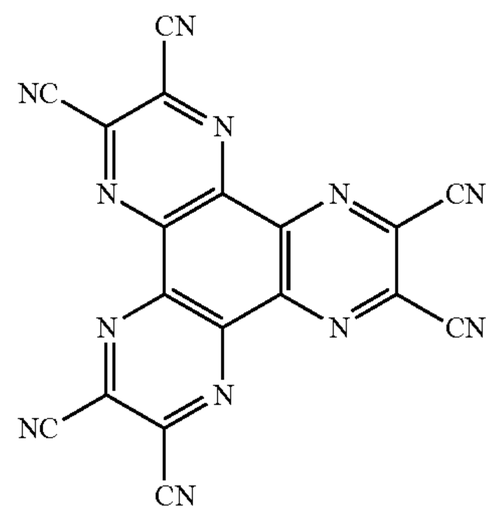


A thickness of the hole transport region may be about 100 Å to about 10000 Å, for example, about 100 Å to about 1000 Å. When the hole transport region includes both of the HIL and the HTL, a thickness of the HIL may be about 100 Å to about 10000 Å, for example, about 100 Å to about 1000 Å, and a thickness of the HTL may be about 50 Å to about 2000 Å, for example, about 100 Å to about 1500 Å. In one embodiment, when the thicknesses of the hole transport region, the HIL, and the HTL satisfy the ranges described above, satisfactory hole injection characteristics are obtained without a substantial increase in a driving voltage.

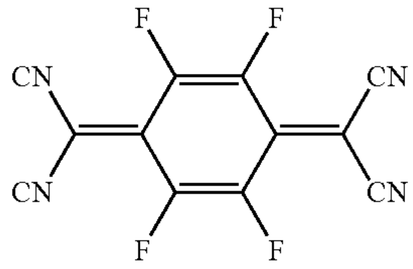
The hole transport region may further include a charge-generating material, in addition to the material described above. The charge-generating material may be uniformly or non-uniformly dispersed in the hole transport region.

The charge-generating material may be, for example, a p-dopant. The p-dopant may be selected from quinone derivatives, metal oxides, and CN-containing compounds, but it is not limited thereto. For example, non-limiting examples of the p-dopant are quinone derivatives (such as tetracyanoquinodimethane (TCNQ), or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinodimethane (F4-TCNQ)); metal oxides (such as tungsten oxides or molybdenym oxides); and Compound HT-D1 below.

Compound HT-D1



F4-TCNQ



The hole transport region may include at least one selected from the buffer layer and the EBL, in addition to the HIL and the HTL. The buffer layer may compensate for an optical resonance distance of light according to a wavelength of the light emitted from the emission layer (EML), and thus may increase the efficiency of light emission. The buffer layer may include any suitable material that may be used (utilized) in the hole transport region. The EBL may reduce or prevent the injection of electrons from the electron transport region.

Then, the EML may be formed on the first electrode **110** or the hole transport region by vacuum deposition, spin coating, casting, LB deposition, inkjet printing, laser printing, LITI, or the like. When the EML is formed using (utilizing) vacuum deposition or spin coating, the deposition and coating conditions may be similar to those for the formation of the HIL.

When the organic light-emitting device **10** is a full color organic light-emitting device, the organic light-emitting device **10** may be patterned into red EML, green EML, and blue EML, according to different EMLs and individual sub-pixels. Alternatively, the EML may have a structure in which the red EML, the green EML, and the blue EML are layered, or a structure in which a red light emission material, a green light emission material, and a blue light emission material are mixed without separation of layers and emit white light. Alternatively, the EML is a white light EML, which includes a color filter or a color converting layer that converts white light into light of desired color.

The EML may include a host and a dopant.

The EML may include the at least one first material represented by Formula 1 above. For example, the host may include the at least one first material represented by Formula 1 above.

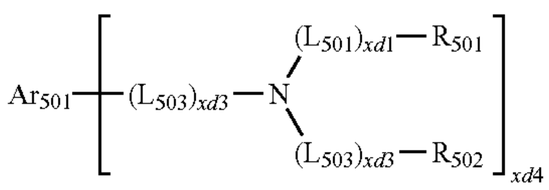
When the EML includes the at least one first material represented by Formula 1 above, the ETL may include the at least one second material represented by Formula 2 above, but each of the EML and ETL is not limited thereto. When the EML includes the at least one first material represented by Formula 1 and the ETL includes the at least one second

material represented by Formula 2, the EML and the ETL may be adjacent to each other.

The dopant may be at least one of a fluorescent dopant and a phosphorescent dopant.

The fluorescent dopant may include a compound represented by Formula 501 below:

Formula 501



In Formula 501,

Ar_{501} may be selected from a naphthalene group, a heptalene group, a fluorene group, a spiro-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, and an indenoanthracene group;

a naphthalene group, a heptalene group, a fluorene group, a spiro-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, and an indenoanthracene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{50} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{501})(Q_{502})(Q_{503})$ (wherein Q_{501} to Q_{503} may be each independently selected from a hydrogen, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_2-C_{60} heteroaryl group);

descriptions of L_{501} to L_{503} may be understood by referring to the description of L_{201} above;

R_{501} and R_{502} may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, carbazole, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

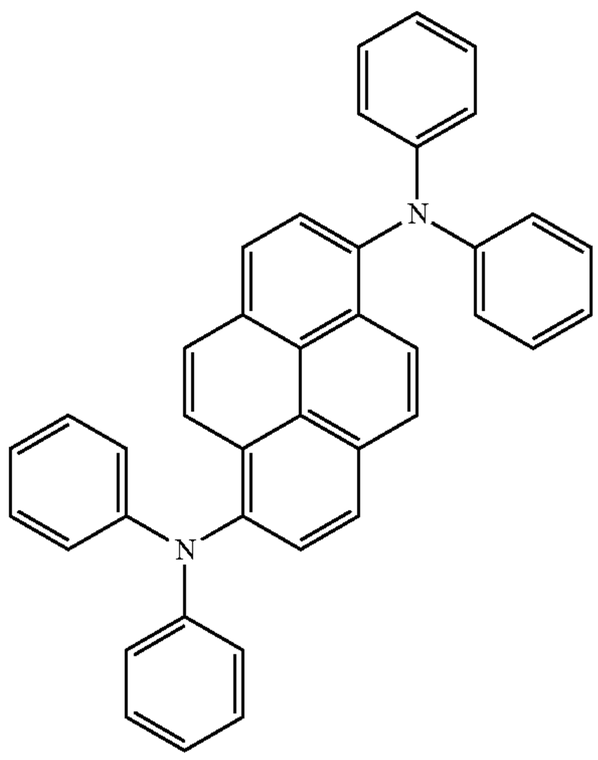
a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, and a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a triazinyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

xd1 to xd3 may be each independently selected from 0, 1, 2, and 3;

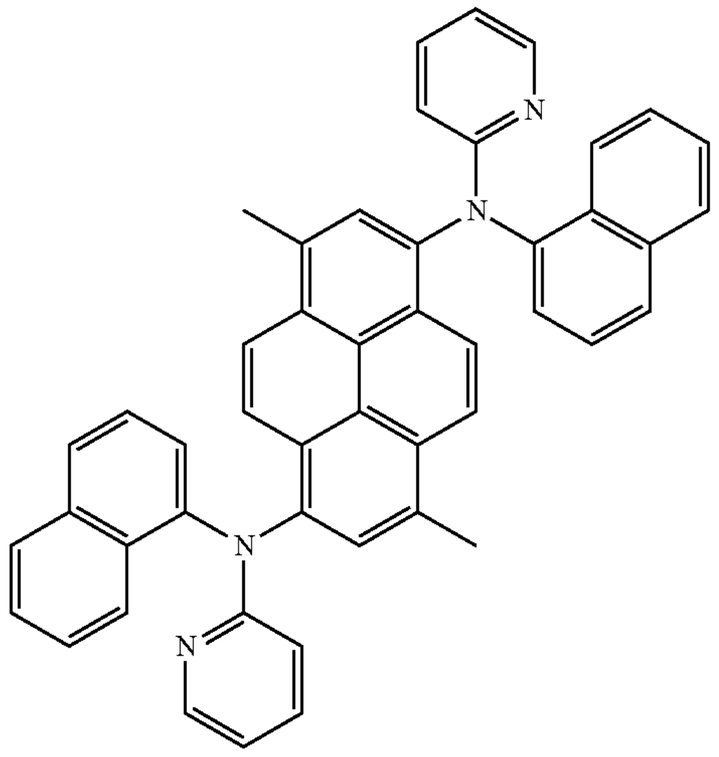
xd4 may be selected from 1, 2, 3, and 4.

The fluorescent dopant may include at least one selected from Compounds FD1 to FD8:

FD1



FD2



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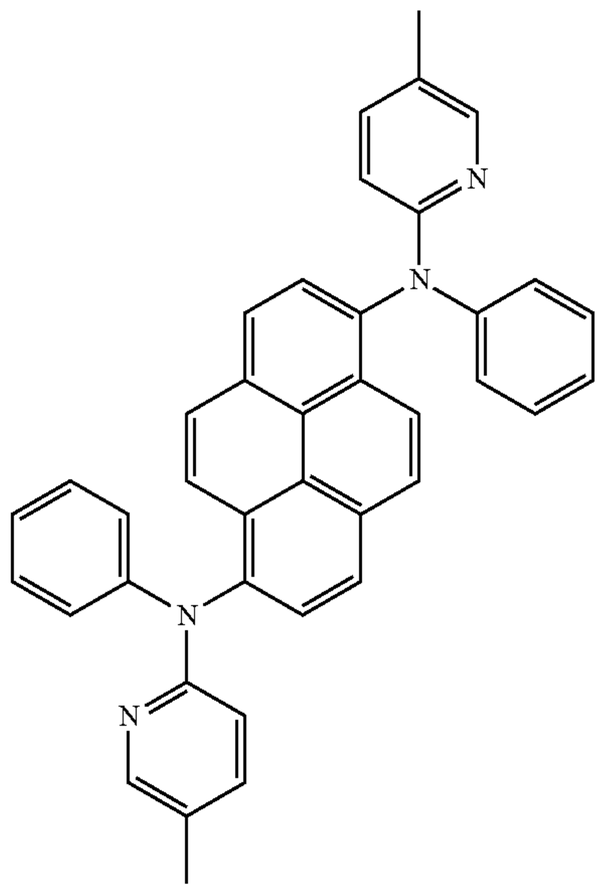
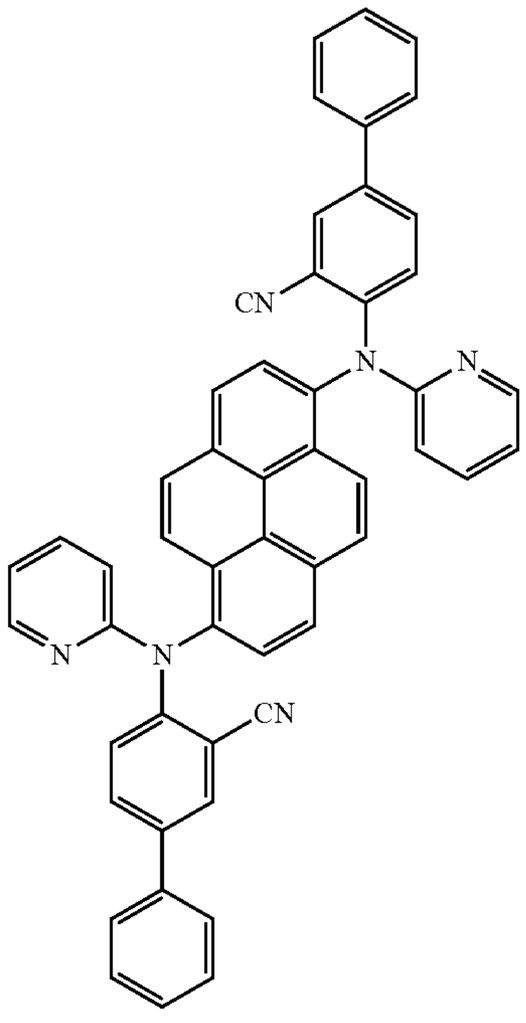
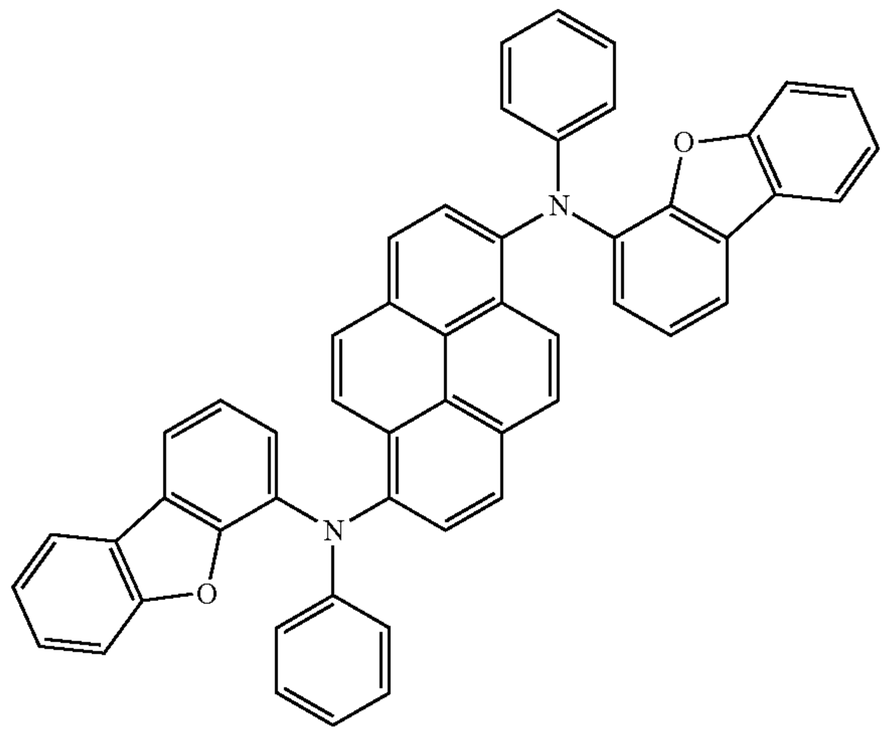
FD3



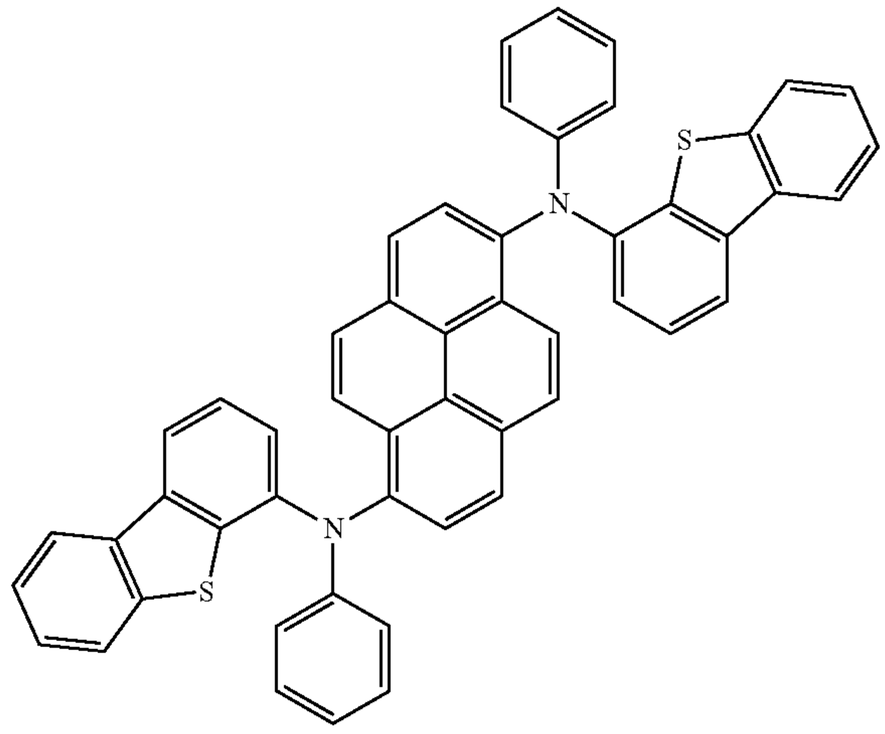
FD4



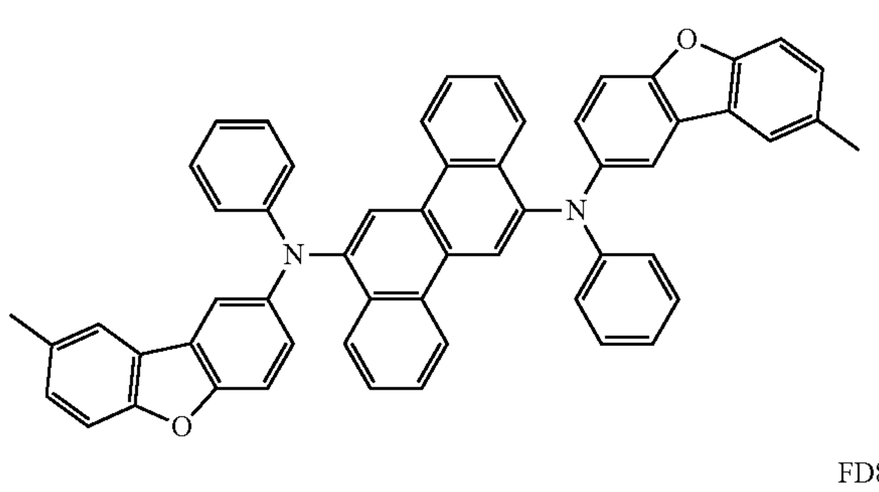
FD5



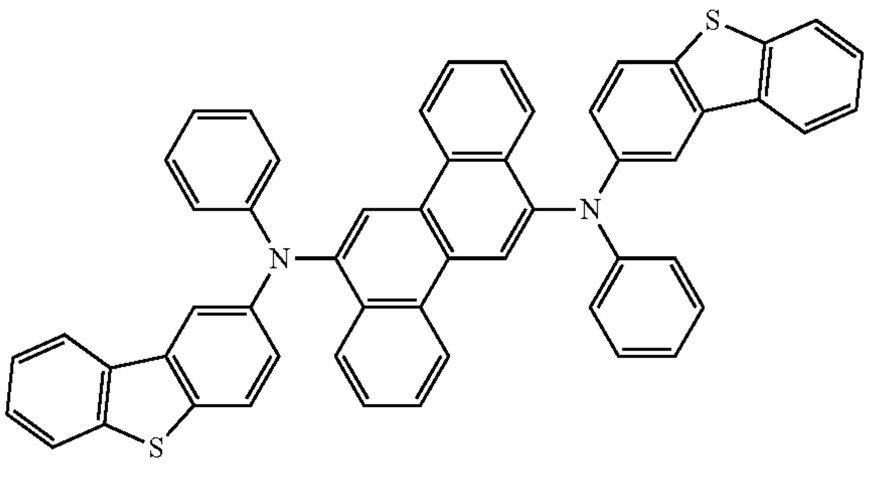
FD6



FD7



FD8



In the EML, an amount of the dopant may generally be about 0.01 parts by weight to about 15 parts by weight based on 100 parts by weight of the host, but it is not limited thereto.

A thickness of the EML may be about 100 Å to about 1000 Å, for example, about 200 Å to about 600 Å. In one embodiment, when the thickness of the EML is in the range described above, the EML has excellent light-emitting ability without a substantial increase in driving voltage.

The electron transport region may be disposed on the EML.

The electron transport region may include at least one of the HBL, the ETL, and the EIL, but it is not limited thereto.

For example, the electron transport region may have a structure in which the ETL, the ETL/EIL, or the HBL/ETL/EIL is sequentially layered on the EML, but it is not limited thereto.

The electron transport region may include an HBL. When the EML includes a phosphorescent dopant, the HBL may be formed to reduce or prevent diffusion of triplet excitons or holes into the ETL.

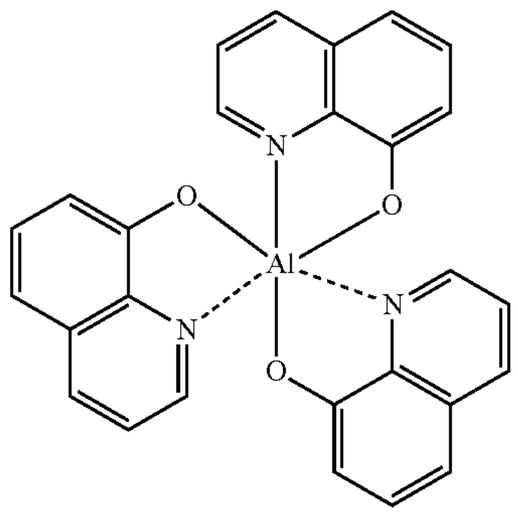
The HBL may include the at least one first material represented by Formula 1. When the hole blocking layer includes the at least one first material represented by Formula 1, the ETL may include the at least one second material represented by Formula 2, but it is not limited thereto. When the HBL includes the at least one first material represented by Formula 1 and the ETL includes the at least one second material represented by Formula 2, the HBL and the ETL may be adjacent to each other.

When the electron transport region includes the HBL, the HBL may be formed on the EML by using (utilizing) various suitable methods such as vacuum deposition, spin coating, casting, LB, inkjet printing, laser printing, or LITI. When the HBL is formed by vacuum deposition or spin coating, the deposition and coating conditions may be similar to those for forming the HIL, though the deposition and coating conditions may vary according to a compound that is used (utilized) to form the HBL.

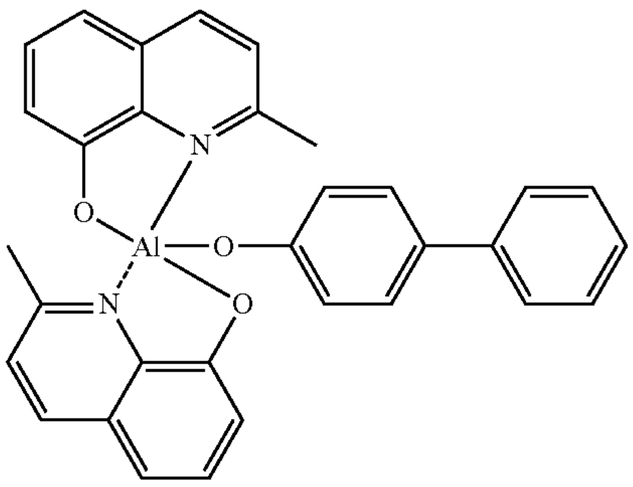
The HBL may include, for example, the at least one second material represented by Formula 2 above.

A thickness of the HBL may be from about 20 Å to about 1,000 Å, and in some embodiments, may be from about 30 Å to about 300 Å. In one embodiment, when the thickness of the HBL is within these ranges, the HBL has a hole blocking transporting ability without a substantial increase in driving voltage. The electron transport region may include an ETL. The ETL may be formed on the EML or the HBL by using (utilizing) various suitable methods such as vacuum deposition, spin coating, casting, LB, inkjet printing, laser printing, or LITI. When the ETL is formed by vacuum deposition or spin coating, the deposition and coating conditions may be similar to those for forming the HIL, though the deposition and coating conditions may vary according to a compound that is used (utilized) to form the ETL.

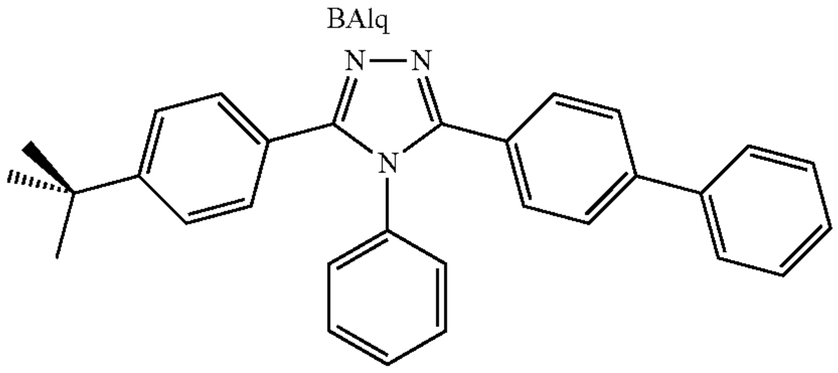
The ETL may include at least one selected from the second material represented by Formula 2 above, BCP and Bphen above, and Alq_3, Balq, TAZ, and NTAZ below, and a compound represented by Formula 601 below.



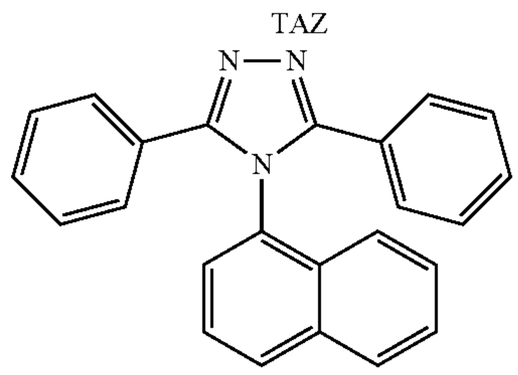
Alq_3



BAlq



TAZ



NTAZ

Formula 601

$$Ar_{601}\text{---}[(L_{601})_{xe1}\text{---}E_{601}]_{xe2}$$

In Formula 601,

Ar_{601} is at least one selected from a naphthalene group, a heptalene group, a fluorene group, a spiro-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, and an indenoanthracene group;

a naphthalene group, a heptalene group, a fluorene group, a spiro-fluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, and an indenoanthracene group, each substituted with at least one selected from deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino

group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_3-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_2-C_{60} heteroaryl group, a non-aromatic condensed polycyclic group, and —$Si(Q_{301})(Q_{302})(Q_{303})$ (wherein, Q_{301} to Q_{303} may be each independently selected from hydrogen, a C_1-C_{50} alkyl group, a C_2-C_{60} alkenyl group, a C_6-C_{60} aryl group, and a C_2-C_{60} heteroaryl group);

description of L_{601} may be the same as and understood by referring to the description of L_{201} above;

E_{601} may be selected from a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

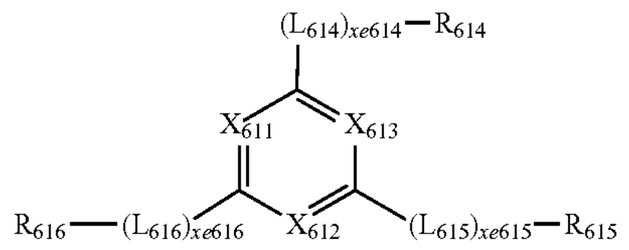
a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coroneryl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group;

xe1 may be selected from 0, 1, 2, and 3; and

xe2 may be selected from 1, 2, 3, and 4.

Alternatively, the ETL may include at least one second material represented by Formula 2 above and/or at least one compound represented by Formula 602 below:

Formula 602



In Formula 602 above,

X_{611} may be N or C-$(L_{611})_{xe611}$-R_{611}; X_{612} may be N or C-$(L_{612})_{xe612}$-R_{612}; X_{613} may be N or C-$(L_{613})_{xe613}$-R_{613}, and at least one of X_{611} to X_{613} may be N;

description for each of L_{611} to L_{616} may be understood by referring to the description of L_{201} herein;

R_{611} to R_{616} may be each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

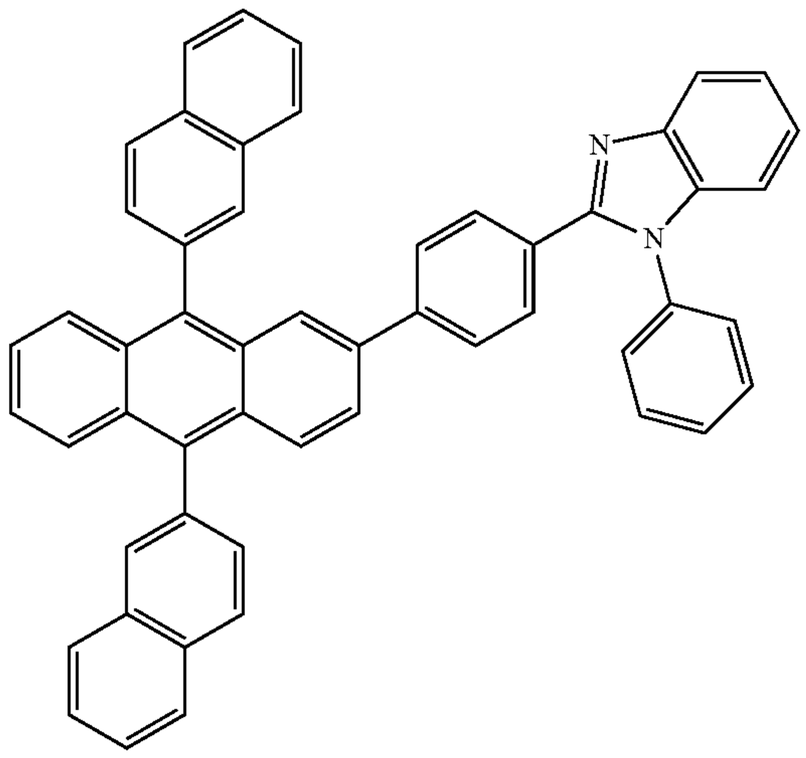
a phenyl group, a naphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzo-fluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a qui-noxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group, each substituted with at least one selected from a deuterium, a halogen atom, a hydroxyl group, a cyano group, a nitro group, an amino group, an

amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an azulenyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a pyrenyl group, a chrysenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, and a triazinyl group; and

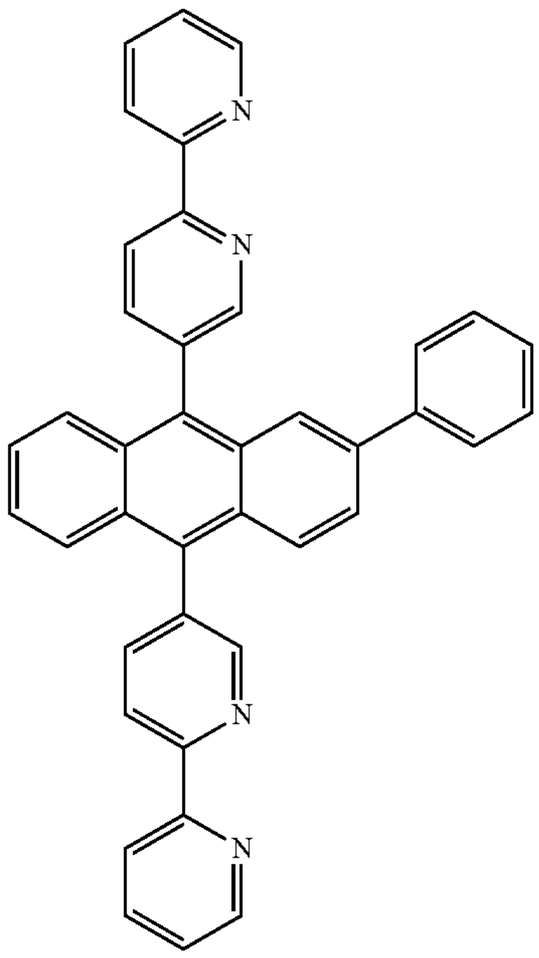
xe611 to xe616 may be each independently selected from 0, 1, 2, and 3.

The compound represented by Formula 601 and the compound represented by Formula 602 above may include at least one selected from Compounds ET1 to ET15.

ET1



ET2



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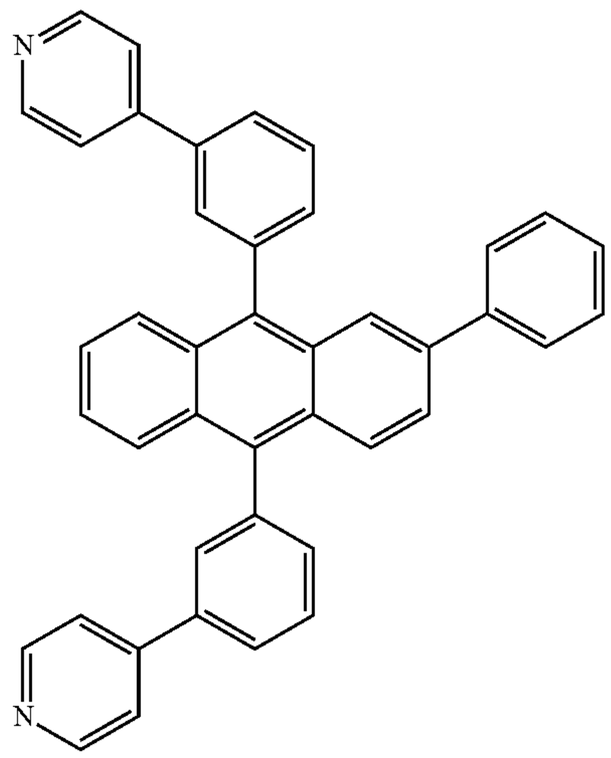
ET3



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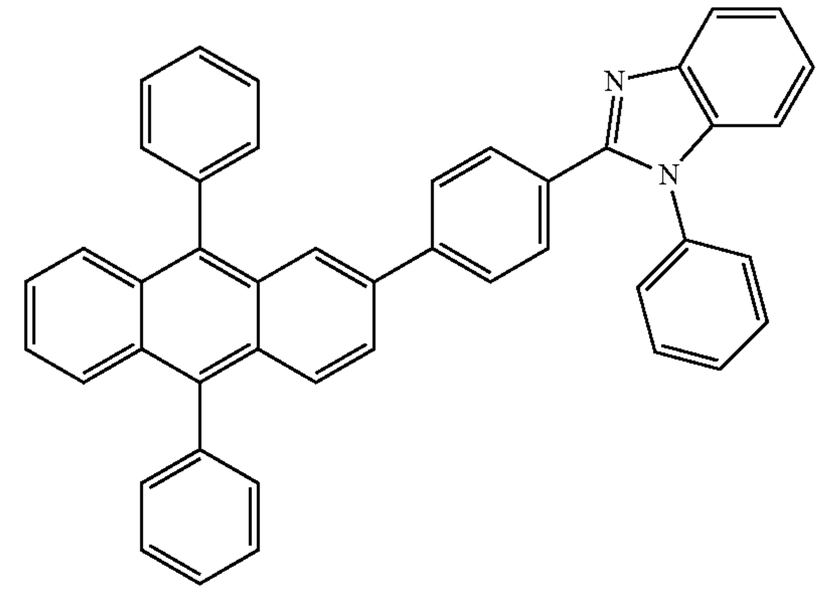
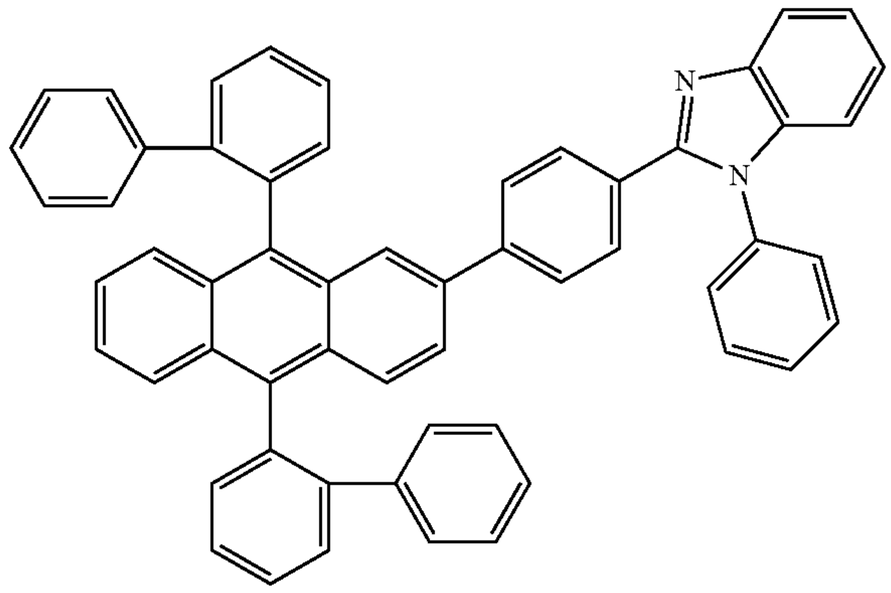
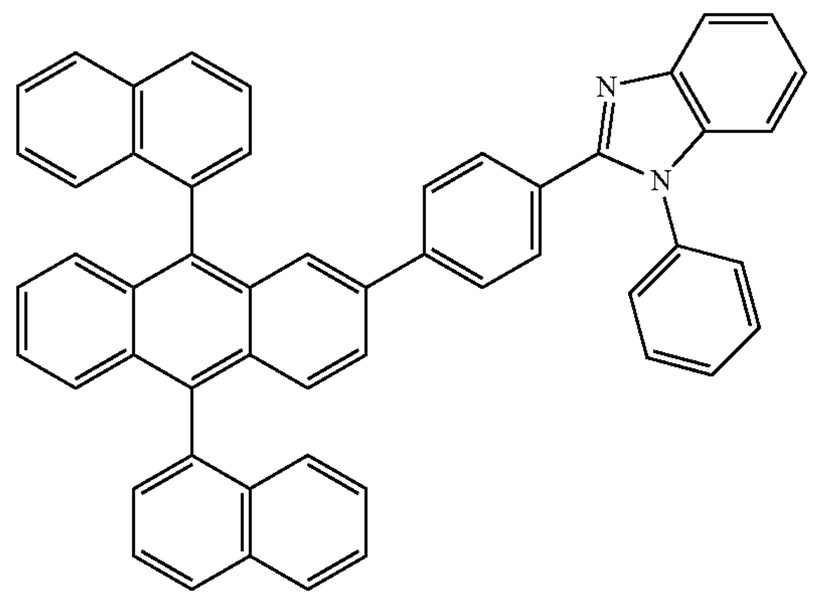


ET5



ET6



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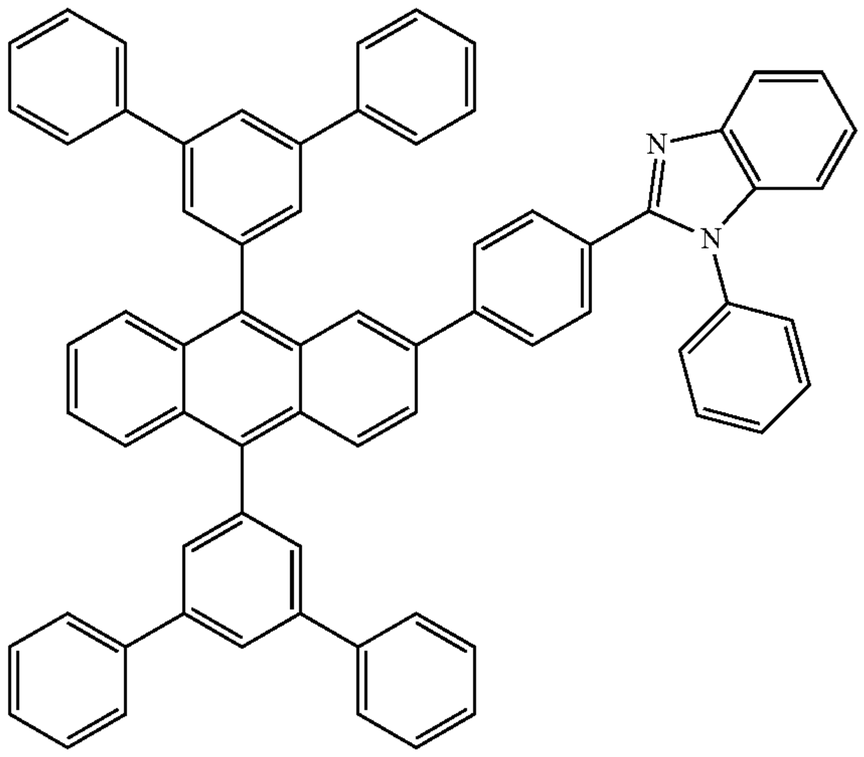
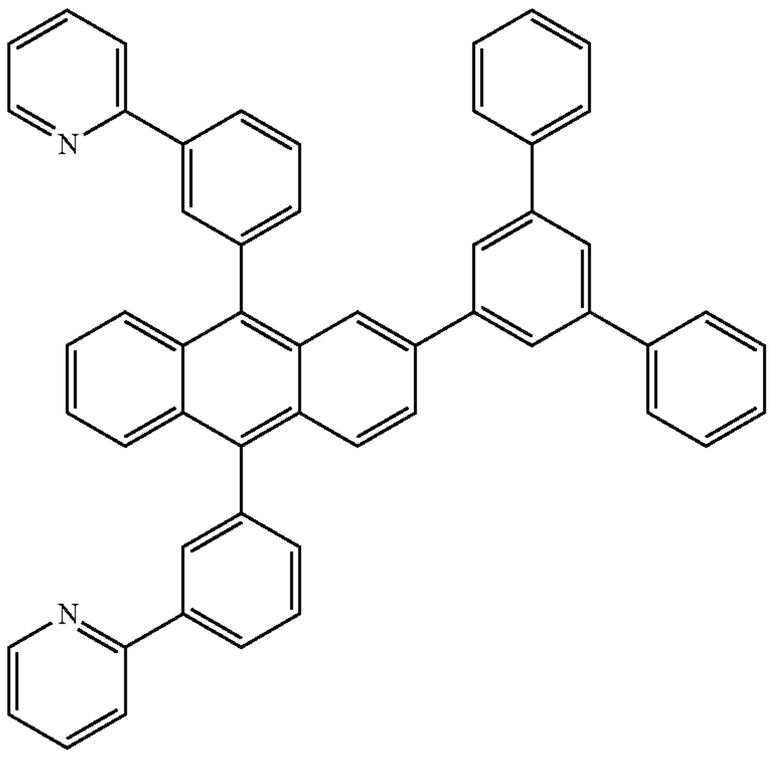
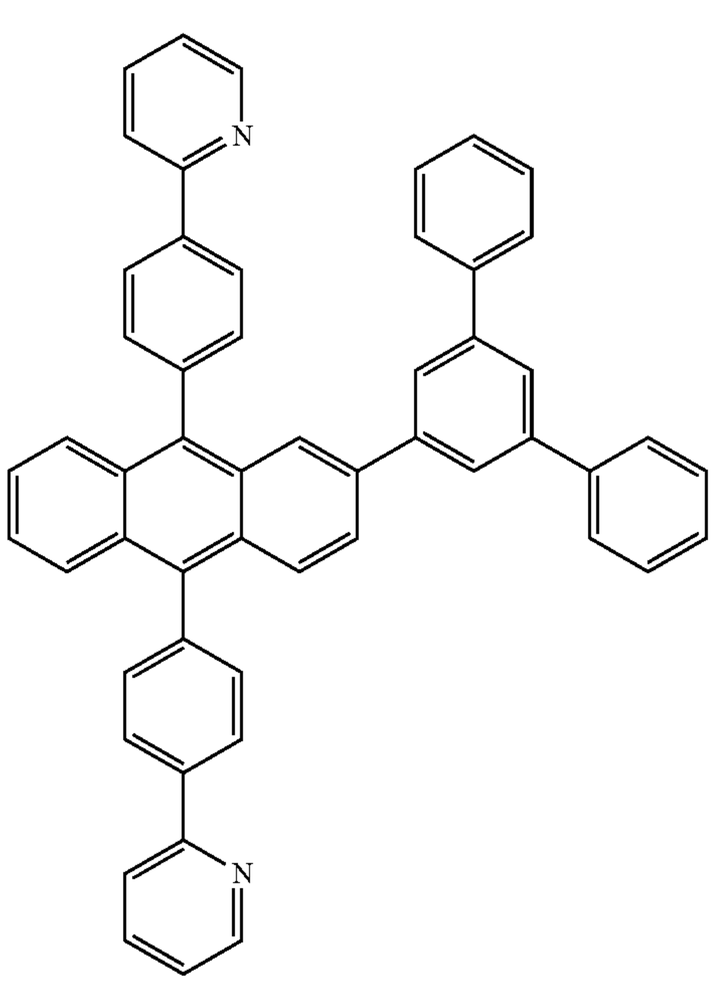
ET7



ET8



ET9



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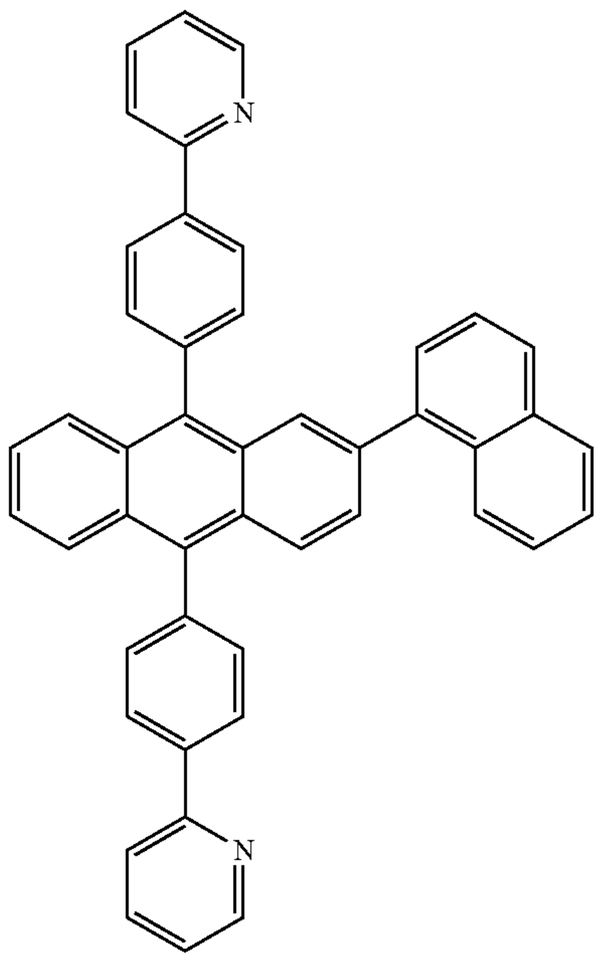
ET10



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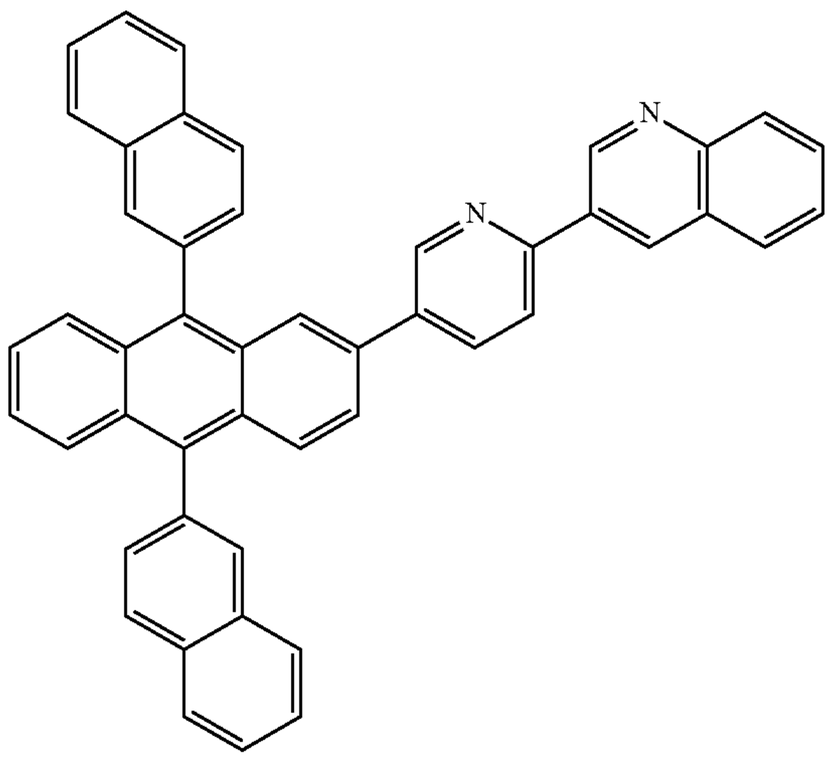
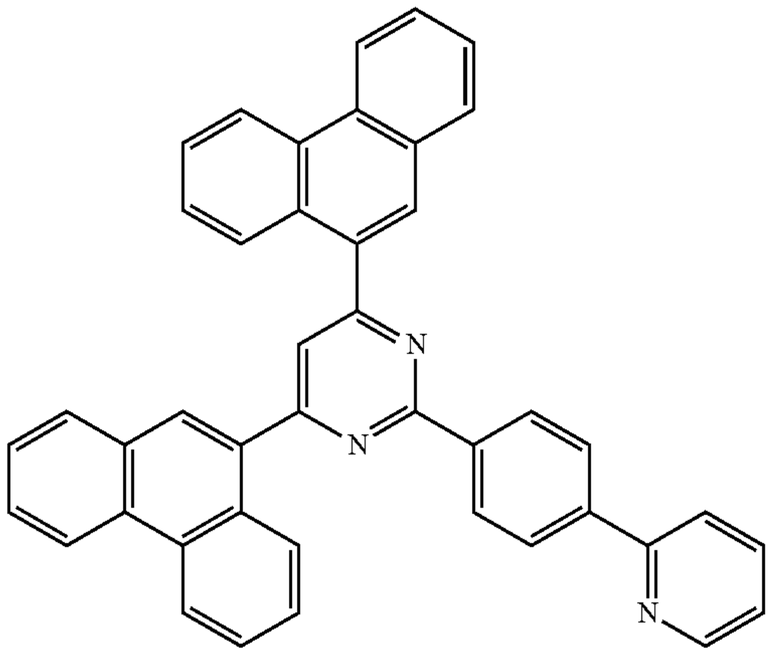


ET12



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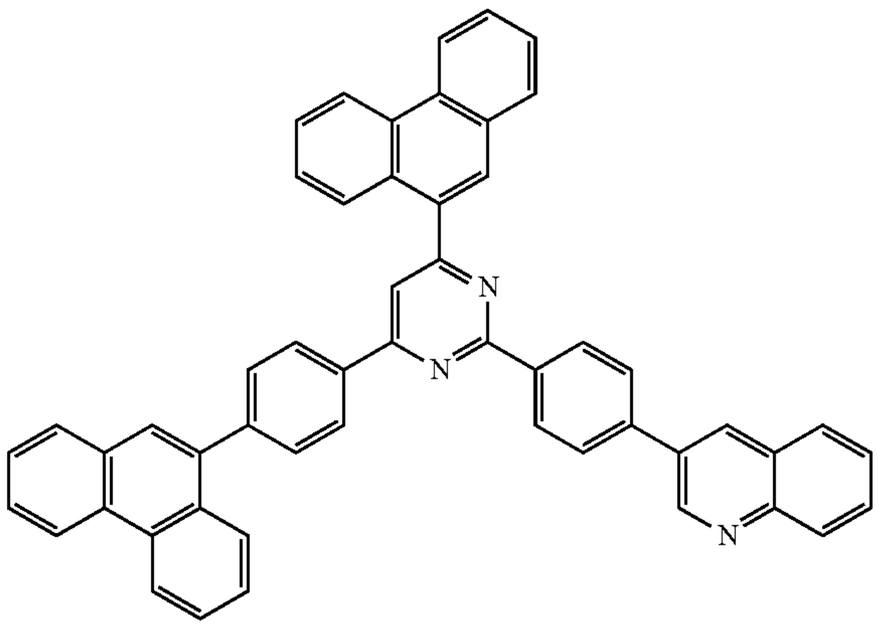
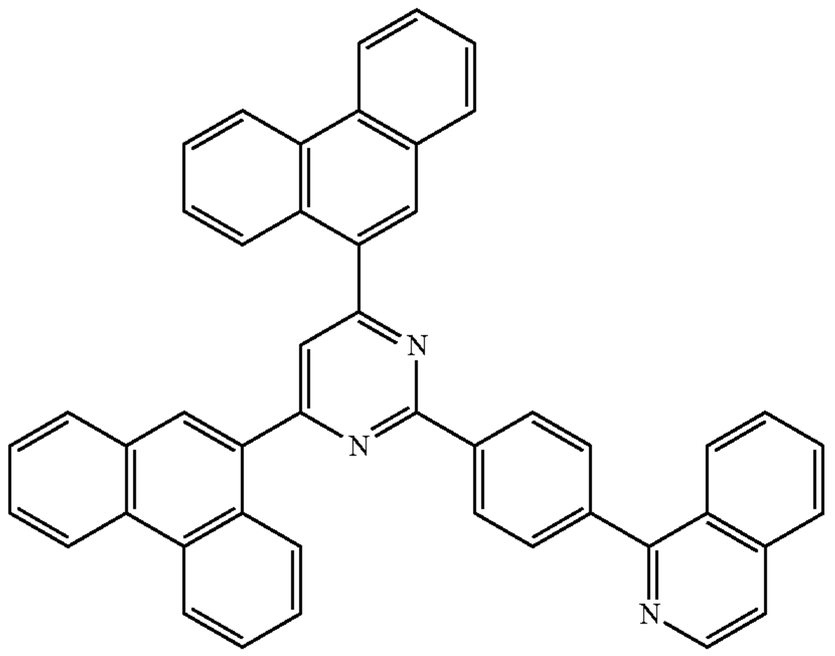
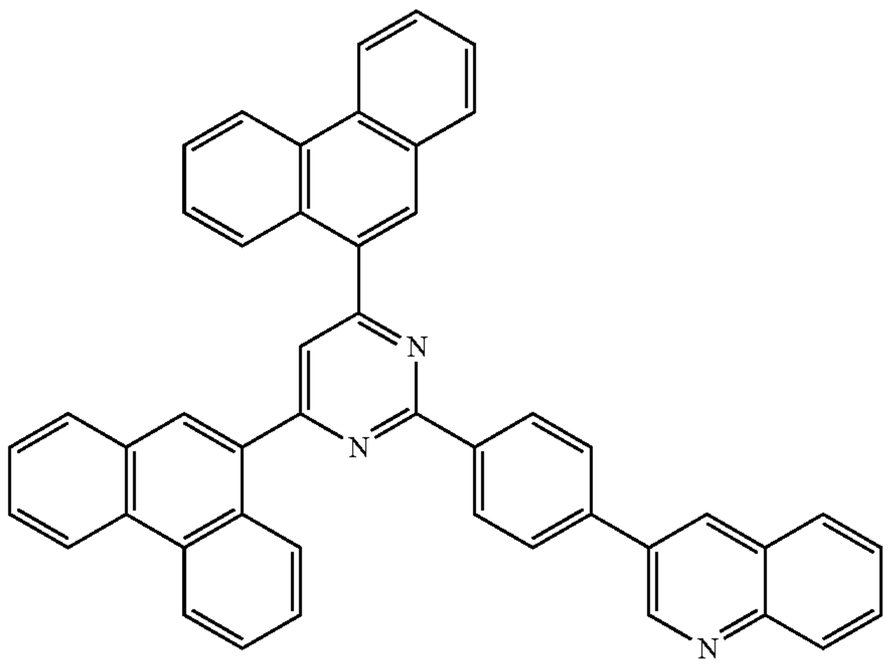
ET13



ET14



ET15

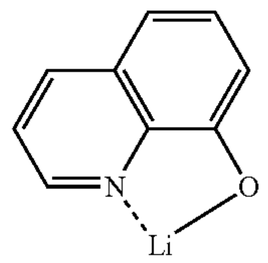


A thickness of the ETL may be about 100 Å to about 1000 Å, for example, about 150 Å to about 500 Å. In one embodiment, when the thickness of the ETL is within the range described above, the ETL has satisfactory electron transport characteristics without a substantial increase in driving voltage.

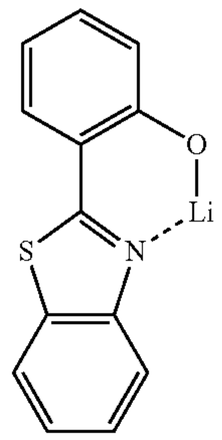
The ETL may further include a metal-containing material in addition to the material described above.

The metal-containing material may include a Li complex. The Li complex may, for example, include compounds ET-D1 (lithium quinolate: LiQ) or ET-D2 illustrated below.

ET-D1



ET-D2



The electron transport region may include an EIL that facilitates electron injection from the second electrode **190**.

The EIL may be formed on the ETL by using (utilizing) various suitable methods such as vacuum deposition, spin coating, casting, LB, inkjet printing, laser printing, or LITI. When the EIL is formed by vacuum deposition or spin coating, the deposition and coating conditions may be similar to those for forming the HIL. When the EIL is formed using (utilizing) vacuum deposition or spin coating, the deposition and coating conditions may be similar to those for the formation of the HIL.

The EIL may include at least one selected from LiF, NaCl, CsF, Li_2O, BaO, and LiQ.

A thickness of the EIL may be about 1 Å to about 100 Å, or about 3 Å to about 90 Å. In one embodiment, when the thickness of the EIL is within the range described above, satisfactory electron injection characteristics are obtained without a substantial increase in driving voltage.

The second electrode **190** is disposed on the organic layer **150** described above. The second electrode **190** may be a cathode, which is an electron injection electrode, in which a material of the second electrode **190** may be a metal, an alloy, an electroconductive compound, or a mixture thereof having a low work function. Detailed examples of the material of the second electrode **190** include lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), and magnesium-silver (Mg—Ag). Alternatively, ITO, IZO, or the like may be used (utilized) as the material of the second electrode **190**. The second electrode **190** may be a reflective electrode, a semi-transmission electrode, or a transmission electrode.

Hereinabove, the organic light-emitting device is described with reference to the drawing, but it is not limited thereto.

As used herein, the C_1-C_{60} alkyl group refers to a linear or branched aliphatic C_1-C_{60} hydrocarbon monovalent group, and detailed examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. As used herein, the C_1-C_{60} alkylene group refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

As used herein, the C_1-C_{60} alkoxy group is a monovalent group having a formula of $—OA_{101}$ (wherein, A_{101} is the

C_1-C_{60} alkyl group) and detailed examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

As used herein, the C_2-C_{60} alkenyl group refers to a C_2-C_{60} alkyl group having one or more carbon-carbon double bonds at a center or end thereof. Examples of the unsubstituted C_2-C_{60} alkenyl group are an ethenyl group, a propenyl group, and a butenyl group. As used herein, the C_2-C_{60} alkenylene group refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group.

As used herein, the C_2-C_{60} alkynyl group refers to an unsubstituted C_2-C_{60} alkyl group having one or more carbon-carbon triple bonds at a center or end thereof. Examples of the C_2-C_{60} alkynyl group are an ethynyl group, a propynyl group, and the like. As used herein, the C_2-C_{60} alkynylene group refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group.

As used herein, the C_3-C_{10} cycloalkyl group refers to a C_3-C_{10} monovalent hydrocarbon monocyclic group, and detailed examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. As used herein, the C_3-C_{10} cycloalkylene group refers to a divalent group having the same structure as the C_3-C_{10} cycloalkyl group.

As used herein, the C_2-C_{10} heterocycloalkyl group refers to a C_2-C_{10} monovalent monocyclic group including at least one selected from N, O, P, and S as a ring-forming atom, and detailed examples thereof include a tetrahydrofuranyl group and a tetrahydrothiophenyl group. As used herein, the C_2-C_{10} heterocycloalkylene group refers to a divalent group having the same structure as the C_2-C_{10} heterocycloalkyl group.

As used herein, the C_3-C_{10} cycloalkenyl group refers to a C_3-C_{10} monovalent monocyclic group having at least one double bond in a ring but without aromaticity, and detailed examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. As used herein, the C_3-C_{10} cycloalkenylene group refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

As used herein, the C_2-C_{10} heterocycloalkenyl group refers to a C_2-C_{10} monovalent monocyclic group including at least one selected from N, O, P, and S as a ring-forming atom, and includes at least one double bond in the ring. Detailed examples of the C_2-C_{10} heterocycloalkenyl group include a 2,3-hydrofuranyl group and a 2,3-hydrothiophenyl group. As used herein, the C_2-C_{10} heterocycloalkenylene group refers to a divalent group having the same structure as the C_2-C_{10} heterocycloalkenyl group.

As used herein, the C_6-C_{60} aryl group refers to a C_6-C_{60} monovalent group having a carbocyclic aromatic system, and the C_6-C_{60} arylene group refers to a divalent group having a C_6-C_{60} carbocyclic aromatic system. Examples of the C_6-C_{60} aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group include two or more rings, the two or more rings may be fused to each other.

As used herein, the C_2-C_{60} heteroaryl group refers to a monovalent group having a C_2-C_{60} carbocyclic aromatic system including at least one heteroatom selected from N, O, P, and S as a ring-forming atom, and the C_2-C_{60} heteroarylene group refers to a divalent group having a C_2-C_{60} carbocyclic aromatic system including at least one heteroatom selected from N, O, P, and S as a ring-forming atom. Examples of the C_2-C_{60} heteroaryl group include a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_2-C_{60} heteroaryl group and the C_2-C_{60} heteroarylene group include two or more rings, the two or more rings may be fused to each other.

As used herein, the C_6-C_{60} aryloxy group refers to a group represented by $—OA_{102}$ (wherein, A_{102} is the C_6-C_{60} aryl group), and the C_6-C_{60} arythio group refers to a group represented by $—SA_{103}$ (wherein, A_{103} is the C_6-C_{60} aryl group).

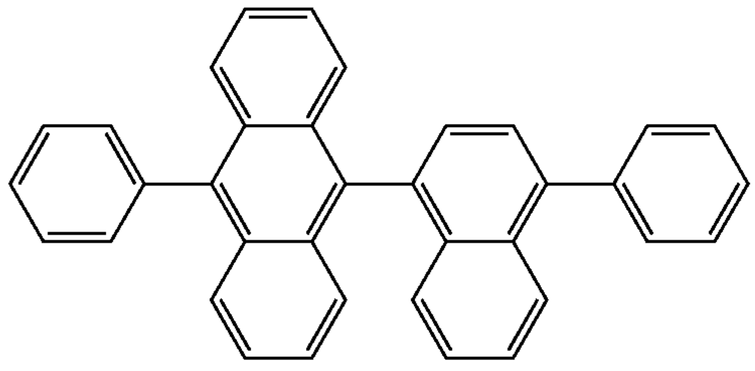
As used herein, the monovalent non-aromatic condensed polycyclic group refers to a monovalent group having two or more rings that are fused to each other, including only carbon as a ring forming atom (for example, carbon number may be 8 to 60), wherein the entire molecule does not have aromacity. Examples of the non-aromatic condensed polycyclic group include a fluorenyl group and the like. As used herein, the divalent non-aromatic condensed polycyclic group may refer to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

As used herein, the monovalent non-aromatic hetero-condensed polycyclic group refers to a monovalent group having two or more rings that are fused to each other, including a heteroatom selected from N, O, P, and S as a ring-forming atom, in addition to carbon (for example, carbon number may be 2 to 60), wherein the entire molecule does not have aromaticity. Examples of the monovalent non-aromatic hetero-condensed polycyclic group includes a carbazolyl group and the like. As used herein, the divalent non-aromatic hetero-condensed polycyclic group refers to a divalent group having the same structure as the monovalent non-aromatic hetero-condensed polycyclic group.

As used herein, the term "Ph" refers to a phenyl group, the term "Me" refers to a methyl group, the term "Et" refers to an ethyl group, and the term "ter-Bu" or "Bu^t" refers to a tert-butyl group.

EXAMPLES

100A



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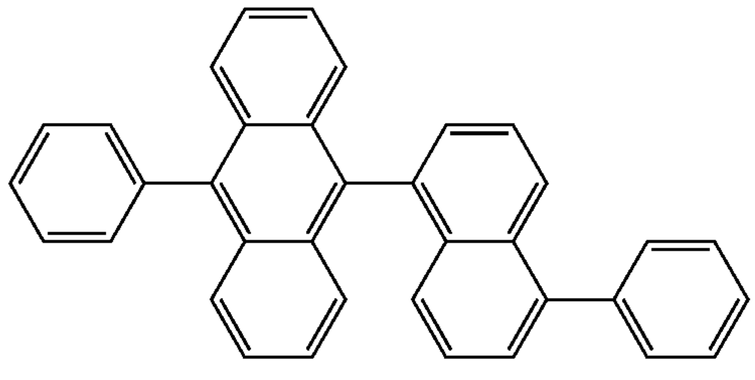

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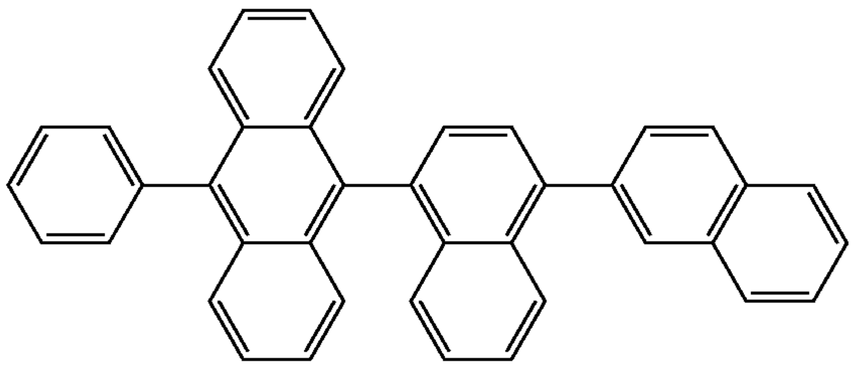

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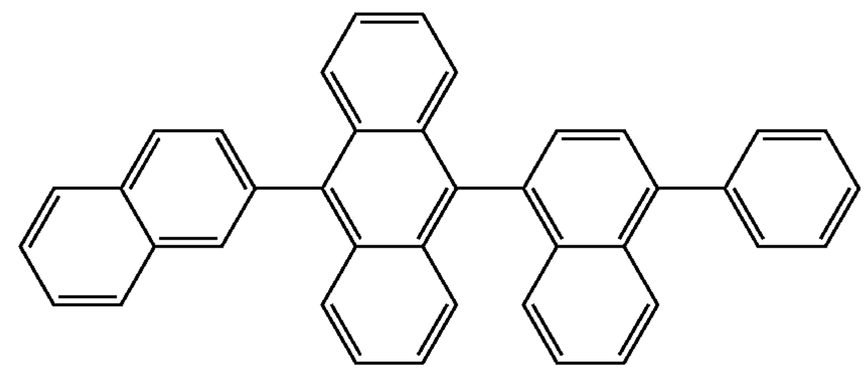

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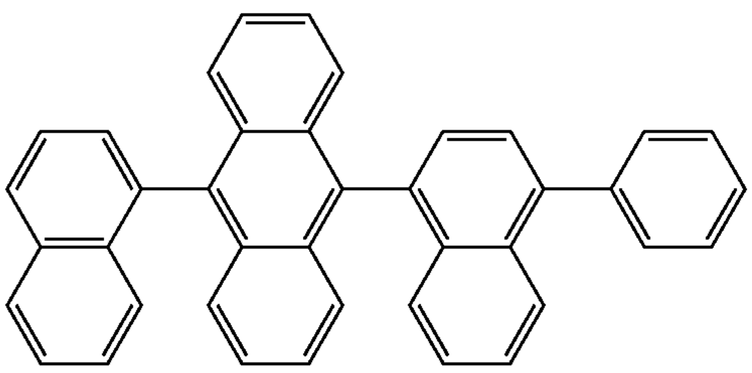

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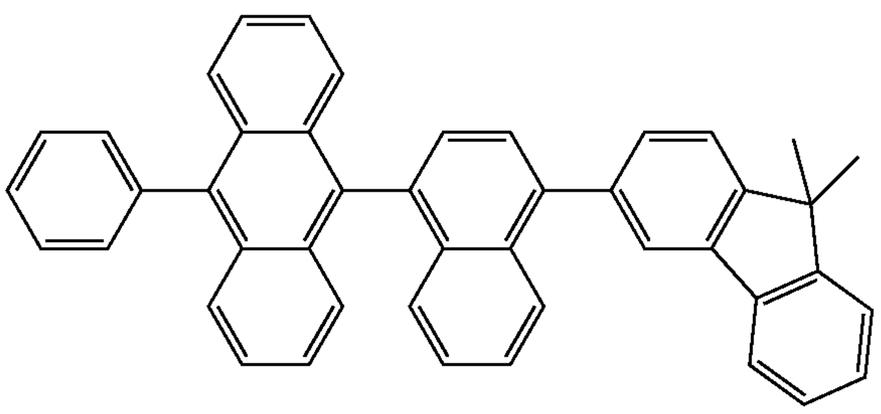

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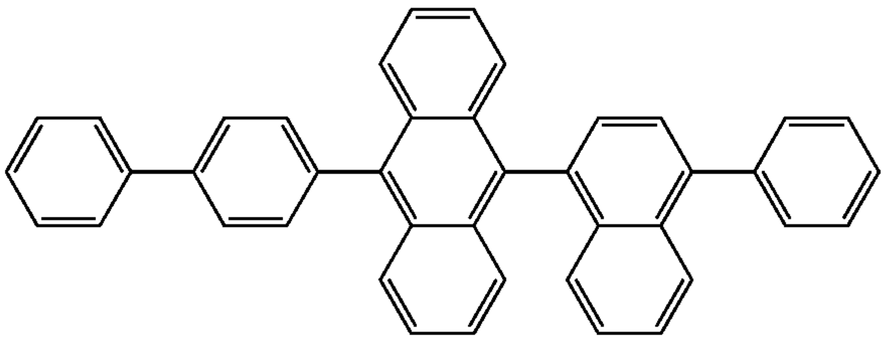

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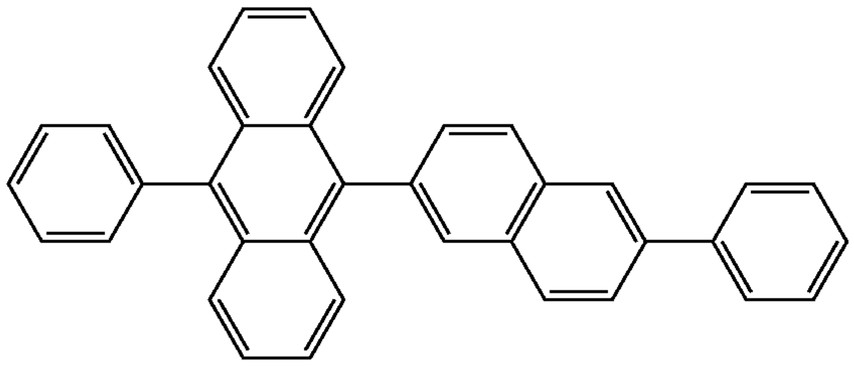

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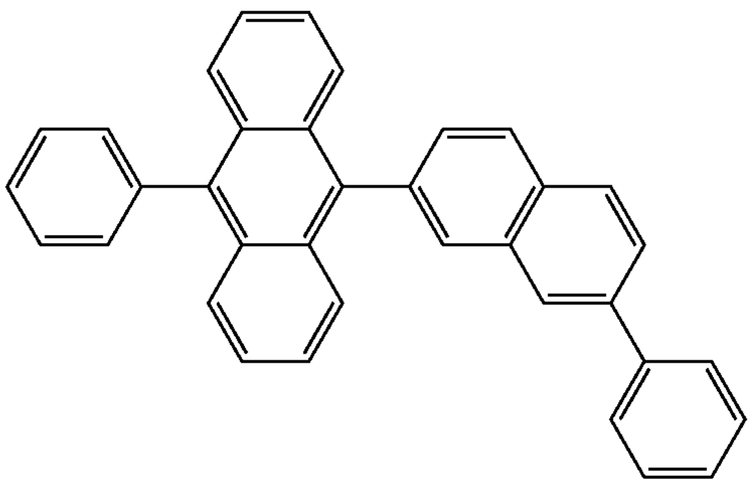
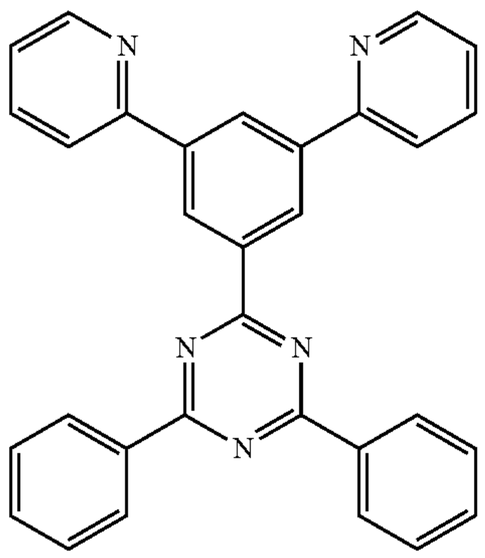


200B



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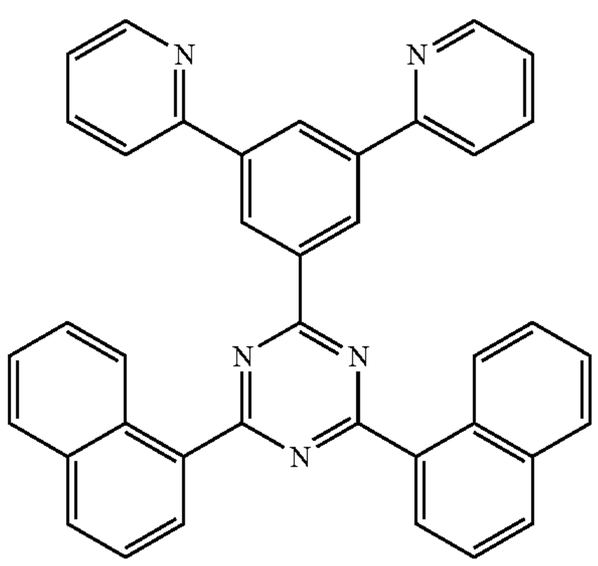
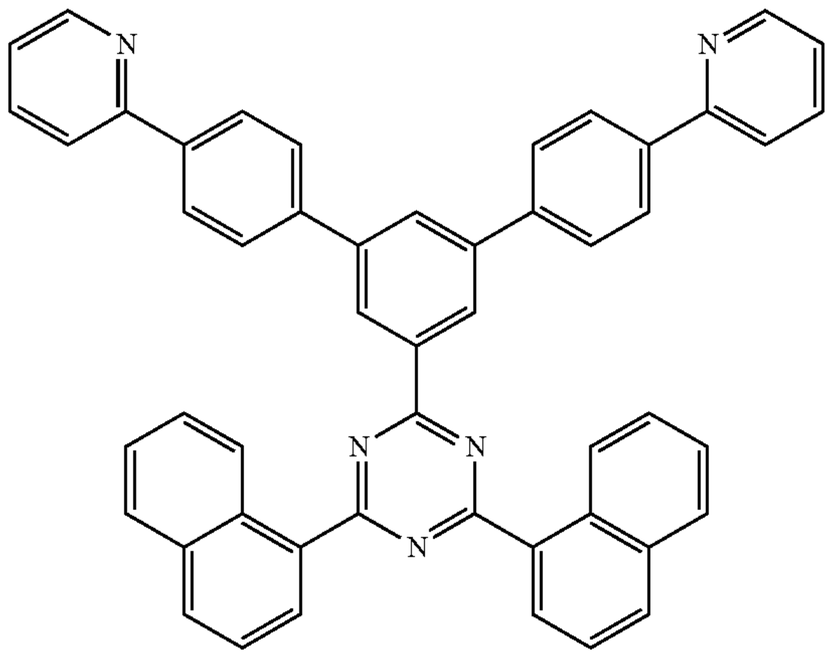


201B



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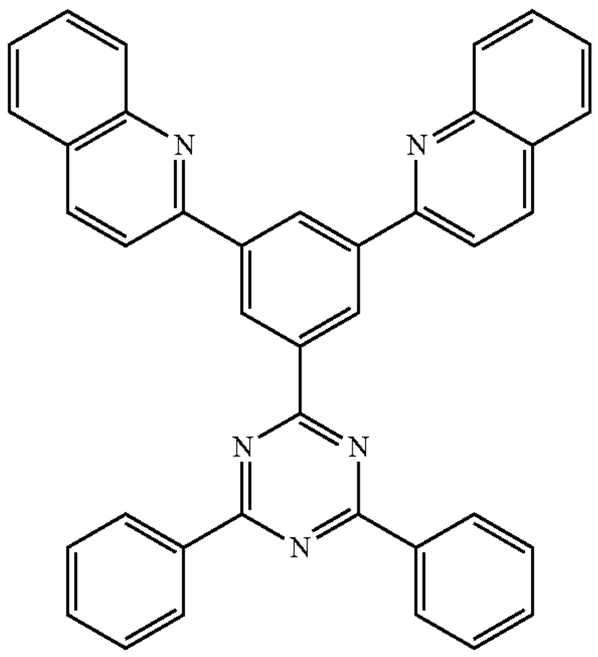
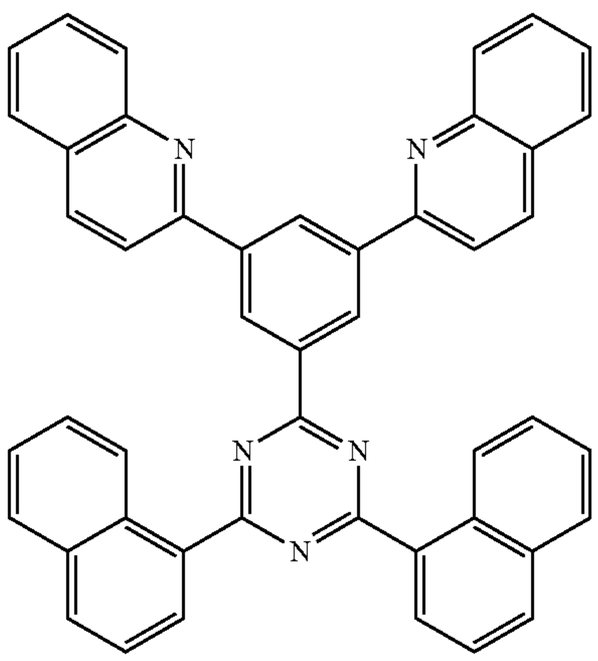
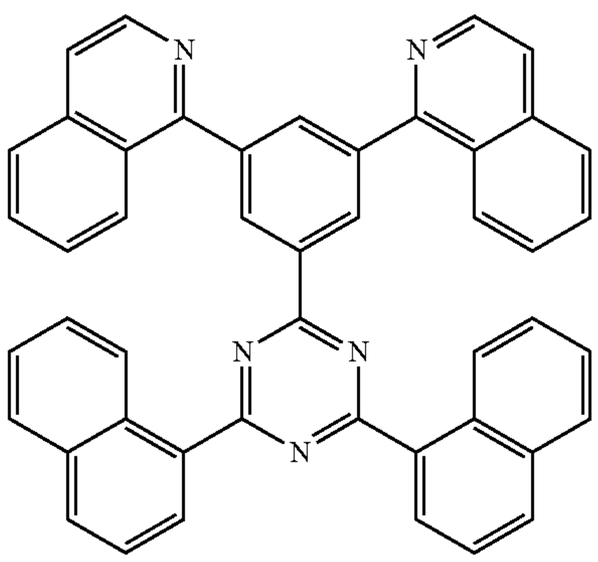
203B



204B



205B



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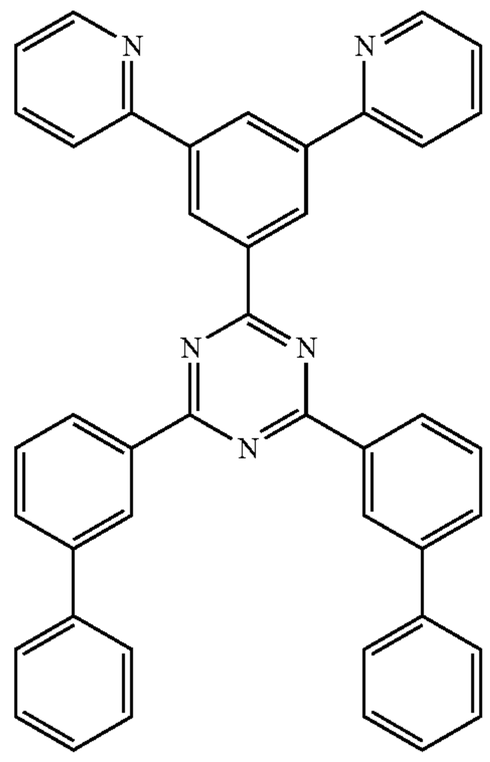
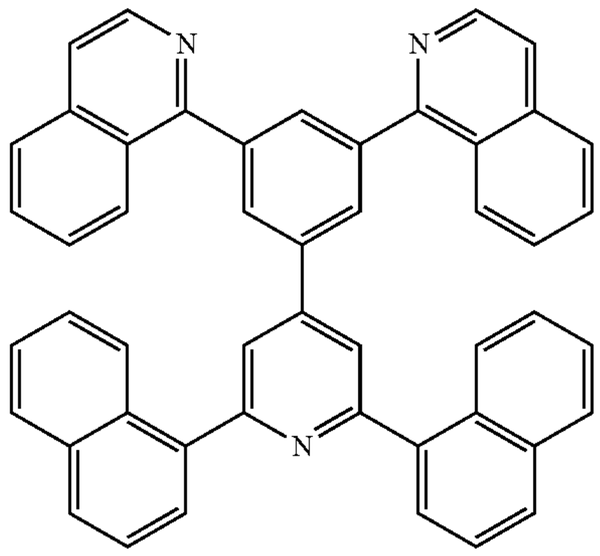
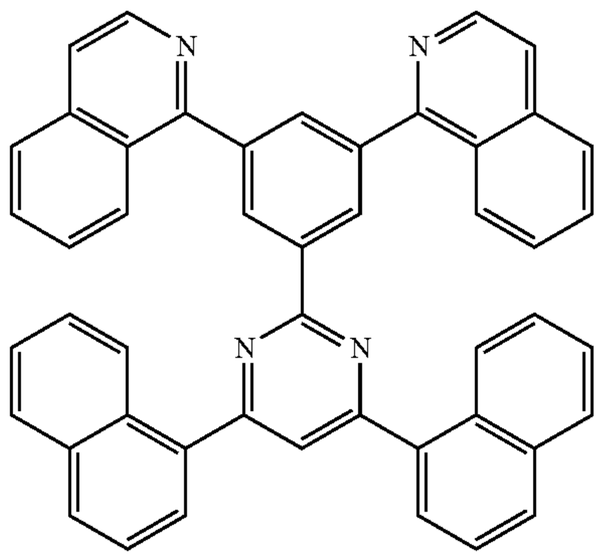
206B



207B



208B



Example 1

As an anode, a 15 Ω/cm^2 ITO glass substrate (1200 Å, Corning) was cut into a size of about 50 mm×50 mm×0.7 mm, ultrasonically washed with isopropyl alcohol for 5 minutes and pure water for 5 minutes, irradiated with UV for 30 minutes, exposed to ozone, and then loaded onto a vacuum deposition device.

HT13 was deposited on the anode to form an HIL having a thickness of 500 Å, HT3 was deposited thereon as a hole-transporting compound to form an HTL having a thickness of 450 Å. Thereafter, Compound 100A and FD1 were co-deposited at a weight ratio of 95:5 to form an EML having a thickness of 300 Å.

Thereafter, Compound 200B was deposited on the EML as an ETL into a thickness of 250 Å, LiF, which is a halogenated alkaline metal, was deposited as an EIL on the

ETL into a thickness of 10 Å, and then Al was vacuum deposited into a thickness of 1500 Å (a negative electrode) to manufacture an organic light-emitting device.

Example 2

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 201B was used (utilized) instead of Compound 200B.

Example 3

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 202B was used (utilized) instead of Compound 200B.

Example 4

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 203B was used (utilized) instead of Compound 200B.

Example 5

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 204B was used (utilized) instead of Compound 200B.

Example 6

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 205B was used (utilized) instead of Compound 200B.

Example 7

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 206B was used (utilized) instead of Compound 200B.

Example 8

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 207B was used (utilized) instead of Compound 200B.

Example 9

An organic light-emitting device was manufactured in the same manner as in Example 1, except that when forming an ETL, Compound 208B was used (utilized) instead of Compound 200B.

Example 10

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 101A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 11

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 102A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 12

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 103A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 13

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 104A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 14

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 105A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 15

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 106A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 16

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 107A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

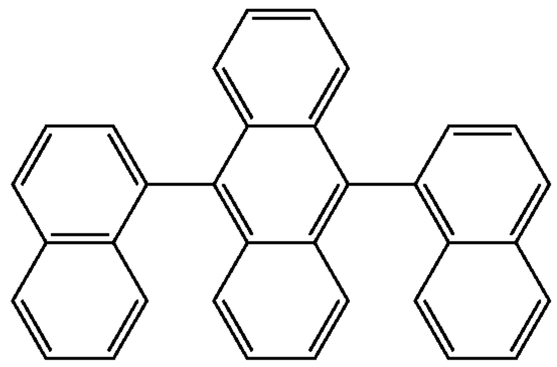
Example 17

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 108A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Comparative Example 1

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound H1 below was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

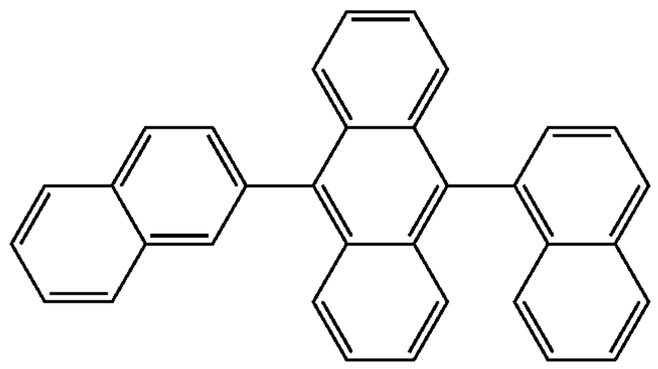
Compound H1



Comparative Example 2

An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound H2 below was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Compound H2



Example 18

As an anode, a 15 Ω/cm^2 ITO glass substrate (1200 Å, Corning) was cut into a size of about 50 mm×50 mm×0.7 mm, ultrasonically washed with isopropyl alcohol for 5 minutes and pure water for 5 minutes, irradiated with UV for 30 minutes, exposed to ozone, and then loaded onto a vacuum deposition device.

HT13 was deposited on the anode to form an HIL having a thickness of 500 Å, HT3 was deposited thereon as a hole-transporting compound to form an HTL having a thickness of 450 Å. Thereafter, Compound 100A and FD1 were co-deposited at a weight ratio of 95:5 to form an EML having a thickness of 300 Å.

Thereafter, Compound 200B and Liq were deposited at a weight ratio of 50:50 on the EML as an ETL into a thickness of 250 Å, LiF, which is a halogenated alkaline metal, was deposited as an EIL on the ETL into a thickness of 10 Å, and then Al was vacuum deposited into a thickness of 1500 Å (a negative electrode) to manufacture an organic light-emitting device.

Example 19

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 201B was used (utilized) instead of Compound 200B when forming an ETL.

Example 20

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 202B was used (utilized) instead of Compound 200B when forming an ETL.

Example 21

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 203B was used (utilized) instead of Compound 200B when forming an ETL.

Example 22

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 204B was used (utilized) instead of Compound 200B when forming an ETL.

Example 23

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 24

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 206B was used (utilized) instead of Compound 200B when forming an ETL.

Example 25

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 207B was used (utilized) instead of Compound 200B when forming an ETL.

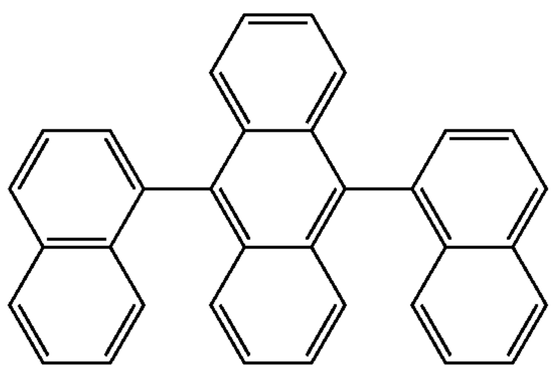
Example 26

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound 208B was used (utilized) instead of Compound 200B when forming an ETL.

Comparative Example 3

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound H1 below was used (utilized) instead of Compound 100A when forming an EML, and Compound 201B was used (utilized) instead of Compound 200B when forming an ETL.

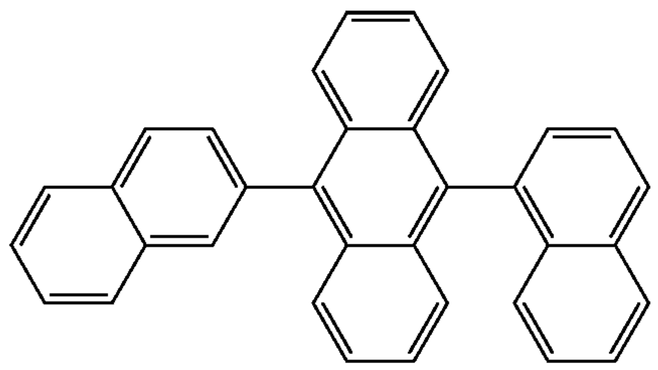
Compound H1



Comparative Example 4

An organic light-emitting device was manufactured in the same manner as in Example 18, except that Compound H2 below was used (utilized) instead of Compound 100A when forming an EML, and Compound 201B was used (utilized) instead of Compound 200B when forming an ETL.

Compound H2



Example 27

As an anode, a 15 Ω/cm^2 ITO glass substrate (1200 Å, Corning) was cut into a size of about 50 mm×50 mm×0.7 mm, ultrasonically washed with isopropyl alcohol for 5 minutes and pure water for 5 minutes, irradiated with UV for 30 minutes, exposed to ozone, and then loaded onto a vacuum deposition device.

HT13 was deposited on the anode to form an HIL having a thickness of 500 Å, HT3 was deposited thereon as a hole-transporting compound to form an HTL having a thickness of 450 Å. Thereafter, Compound 100A and FD1 were co-deposited at a weight ratio of 95:5 to form an EML having a thickness of 300 Å.

Thereafter, Compound 200B was deposited as an HBL on the EML into a thickness of 100 Å, Bphen and Liq were deposited at a weight ratio of 50:50 on the EML as an ETL into a thickness of 150 Å, LiF, which is a halogenated alkaline metal, was deposited as an EIL on the ETL into a thickness of 10 Å, and then Al was vacuum deposited thereon into a thickness of 1500 Å (a negative electrode) to manufacture an organic light-emitting device.

Example 28

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 201B was used (utilized) instead of Compound 200B when forming an ETL.

Example 29

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 202B was used (utilized) instead of Compound 200B when forming an ETL.

Example 30

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 203B was used (utilized) instead of Compound 200B when forming an ETL.

Example 31

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 204B was used (utilized) instead of Compound 200B when forming an ETL.

Example 32

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 33

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 206B was used (utilized) instead of Compound 200B when forming an ETL.

Example 34

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 207B was used (utilized) instead of Compound 200B when forming an ETL.

Example 35

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 208B was used (utilized) instead of Compound 200B when forming an ETL.

Example 36

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 101A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 37

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 102A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 38

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 103A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 39

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 104A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 40

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 105A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 41

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 106A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Example 42

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 107A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

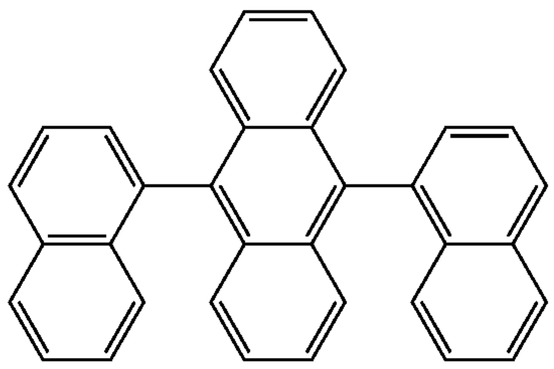
Example 43

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound 108A was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Comparative Example 5

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound H1 below was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

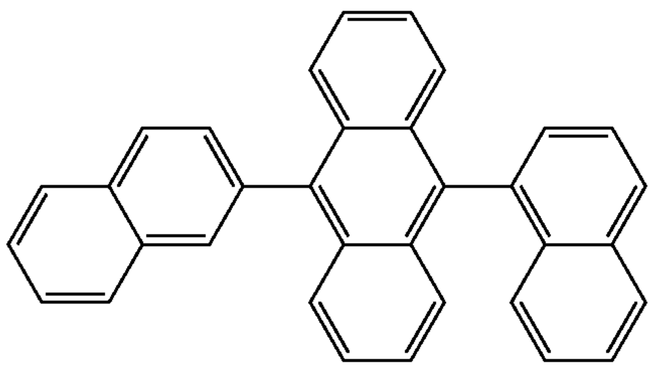
Compound H1



Comparative Example 6

An organic light-emitting device was manufactured in the same manner as in Example 27, except that Compound H2 below was used (utilized) instead of Compound 100A when forming an EML, and Compound 205B was used (utilized) instead of Compound 200B when forming an ETL.

Compound H2



Evaluation Example

Efficiency and T80 lifespan of the organic light-emitting devices in Examples 1 to 43 and Comparative Examples 1 to 6 were evaluated by using (utilizing) a PR650 spectroscan source measurement unit (a product of PhotoResearch). T80 refers to an amount of time taken for the level of brightness to reach a level that is 80% of the initial level of brightness. Results are as shown in Table 1, Table 2 and Table 3 below.

TABLE 1

	EML	ETL	Efficiency (cd/A)	T80 lifespan (time)
Example 1	100A	200B	5.2	120
Example 2	100A	201B	5.3	130
Example 3	100A	202B	5.5	110
Example 4	100A	203B	5.4	100
Example 5	100A	204B	5.5	110
Example 6	100A	205B	5.7	120
Example 7	100A	206B	5.6	100
Example 8	100A	207B	5.5	130
Example 9	100A	208B	5.7	120
Example 10	101A	205B	5.6	120
Example 11	102A	205B	5.8	130
Example 12	103A	205B	5.4	120
Example 13	104A	205B	5.3	120
Example 14	105A	205B	5.8	110
Example 15	106A	205B	5.2	100
Example 16	107A	205B	5.5	130
Example 17	108A	205B	5.4	120
Comparative Example 1	H1	205B	4.9	70
Comparative Example 2	H2	205B	4.7	80

TABLE 2

	EML	ETL	Efficiency (cd/A)	T80 lifespan (time)
Example 18	100A	200B:Liq	5.1	130
Example 19	100A	201B:Liq	5.3	140
Example 20	100A	202B:Liq	5.4	120
Example 21	100A	203B:Liq	5.4	120
Example 22	100A	204B:Liq	5.4	110
Example 23	100A	205B:Liq	5.6	120
Example 24	100A	206B:Liq	5.5	110
Example 25	100A	207B:Liq	5.4	140
Example 26	100A	208B:Liq	5.7	120
Comparative Example 3	H1	201B:Liq	4.8	70
Comparative Example 4	H2	201B:Liq	4.6	80

TABLE 3

	EML	HBL	ETL	Efficiency (cd/A)	Lifespan (time)
Example 27	100A	200B	BPhen:Liq	5.3	120
Example 28	100A	201B	BPhen:Liq	5.3	130
Example 29	100A	202B	BPhen:Liq	5.4	120
Example 30	100A	203B	BPhen:Liq	5.3	110
Example 31	100A	204B	BPhen:Liq	5.4	120
Example 32	100A	205B	BPhen:Liq	5.6	130
Example 33	100A	206B	BPhen:Liq	5.5	100
Example 34	100A	207B	BPhen:Liq	5.3	120
Example 35	100A	208B	BPhen:Liq	5.5	130
Example 36	101A	205B	BPhen:Liq	5.6	140
Example 37	102A	205B	BPhen:Liq	5.5	140
Example 38	103A	205B	BPhen:Liq	5.5	130
Example 39	104A	205B	BPhen:Liq	5.4	120
Example 40	105A	205B	BPhen:Liq	5.7	120
Example 41	106A	205B	BPhen:Liq	5.1	110
Example 42	107A	205B	BPhen:Liq	5.6	130
Example43	108A	205B	BPhen:Liq	5.6	120
Comparative Example5	H1	205B	BPhen:Liq	4.9	70
Comparative Example6	H2	205B	BPhen:Liq	4.7	80

According to Tables 1 to 3, the organic light-emitting devices in Examples 1 to 43 showed higher efficiency and longer lifespan than the organic light-emitting devices in Comparative Examples 1 to 6.

As described above, according to the one or more of the above embodiments of the present invention, an organic light-emitting device according to an embodiment of the present invention may show high efficiency, high heat resistance, and a long lifespan.

It should be understood that the example embodiments described therein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

While one or more embodiments of the present invention have been described with reference to the FIGURE, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims, and equivalents thereof.

What is claimed is:

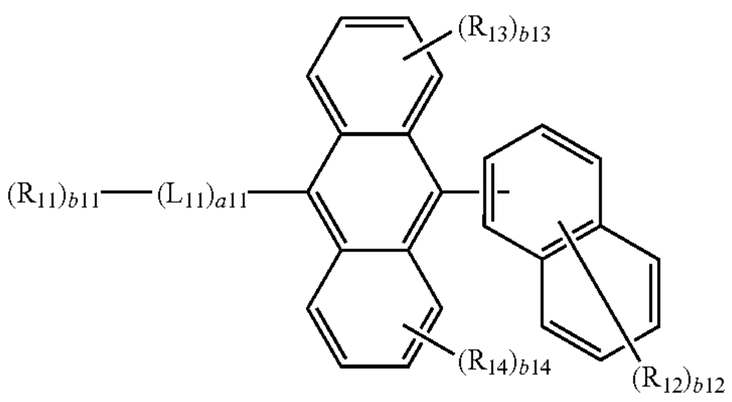
1. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

an organic layer between the first electrode and the second electrode, wherein the organic layer comprises at least one first material represented by Formula 1 below, and at least one second material represented by Formula 2 below:

Formula 1



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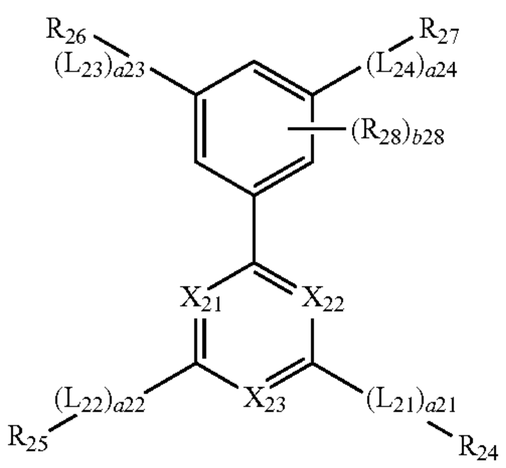
Formula 2



in Formulae 1 and 2,

X_{21} is CR_{21} or a nitrogen atom (N); X_{22} is CR_{22} or N; X_{23} is CR_{23} or N;

L_{11}, and L_{21} to L_{24} are each independently selected from a substituted or unsubstituted C_6-C_{60} arylene group and a substituted or unsubstituted C_1-C_{60} heteroarylene group;

a11, and a21 to a24 are each independently 0 or 1;

R_{11}, R_{12} and R_{24} to R_{27} are each independently selected from a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed hetero-polycyclic group;

b11 and b12 are each independently selected from 1, 2, and 3;

R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_1)(Q_2)(Q_3)$;

b13 and b14 are each independently selected from 1, 2, 3, and 4;

b28 is selected from 1, 2, and 3;

at least one substituent of the substituted C_6-C_{60} arylene group, substituted C_1-C_{60} heteroarylene group, substituted C_6-C_{60} aryl group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, substituted monovalent non-aromatic condensed hetero-polycyclic group, substituted C_1-C_{60} alkyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, and substituted C_6-C_{60} aryloxy group is selected from:

deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt

thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{11})(Q_{12})(Q_{13})$;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group;

a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_2-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_2-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arythio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed hetero-polycyclic group, and —$Si(Q_{21})(Q_{22})(Q_{23})$; and

—$Si(Q_{31})(Q_{32})(Q_{33})$; wherein,

Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} are each independently selected from a C_1-C_{60} alkyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed hetero-polycyclic group.

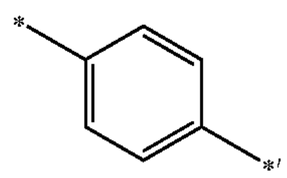
2. The organic light-emitting device of claim **1**, wherein L_{11}, and L_{21} to L_{24} are each independently selected from a phenylene group, a naphthylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an indolylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a benzofuranylene group, a benzothiophenylene group, a triazolylene group, a tetrazolylene group, a triazinylene group, a dibenzofuranylene group, and a dibenzothiophenylene group; and

a phenylene group, a naphthylene group, a phenanthrenylene group, an anthracenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a pyrrolylene group, a thiophenylene group, a furanylene group, an imidazolylene group, a pyridinylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, an indolylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a benzofuranylene group, a benzothiophenylene group, a triazolylene group, a tetrazolylene group, a triazinylene group, a dibenzofuranylene group, and a dibenzothiophenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a thiadiazolyl group, and an imidazopyridinyl group.

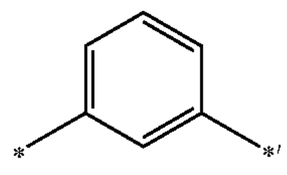
3. The organic light-emitting device of claim **1**, wherein L_{11}, and L_{21} to L_{24} are each independently selected from a phenylene group, a naphthylene group, a pyridinylene group, a quinolinylene group, and an isoquinolinylene group; and

a phenylene group, a naphthylene group, a pyridinylene group, a quinolinylene group, and an isoquinolinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, and a naphthyl group.

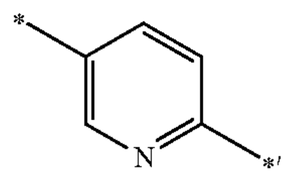
4. The organic light-emitting device of claim 1, wherein L_{11}, and L_{21} to L_{24} are each independently a group selected from Formulae 3-1 to 3-6 below:



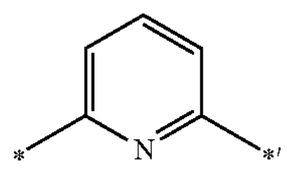
3-1



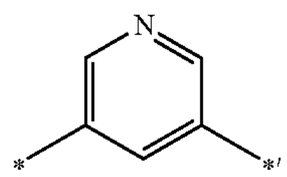
3-2



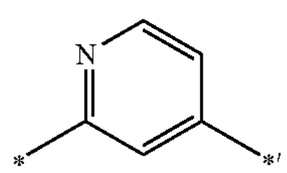
3-3



3-4



3-5



3-6

in Formulae 3-1 to 3-6,

* and *' are each a binding site to a neighboring atom.

5. The organic light-emitting device of claim 1, wherein a11, and a21 to a24 are each independently 0.

6. The organic light-emitting device of claim 1, wherein R_{11}, R_{12} and R_{24} to R_{27} are each independently selected from a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a

triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

7. The organic light-emitting device of claim **1**, wherein R_{11}, R_{12} and R_{24} to R_{27} are each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

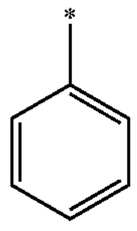
a phenyl group, a naphthyl group, a fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, a naphthyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group.

8. The organic light-emitting device of claim **1**, wherein R_{11}, R_{12} and R_{24} to R_{27} are each independently selected from a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group; and

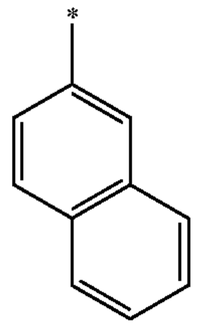
a phenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a phenyl group, a naphthyl group, a pyridinyl group, a quinolinyl group, and an isoquinolinyl group.

9. The organic light-emitting device of claim **1**, wherein R_{11} and R_{12} are each independently selected from Formulae 4-1 to 4-5, 4-23, and 4-24 below:

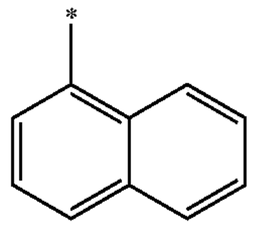
4-1



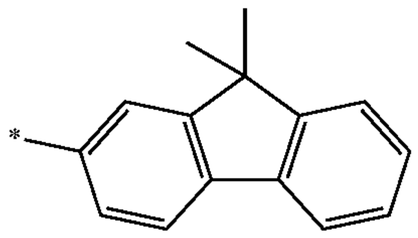
4-2



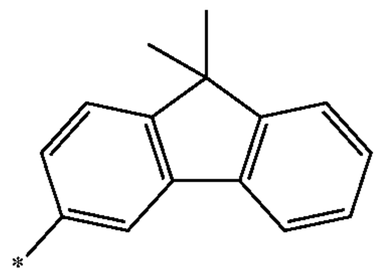
4-3



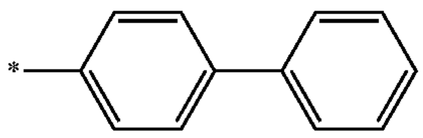
4-4



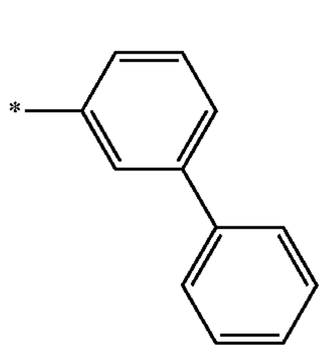
4-5



4-23



4-24

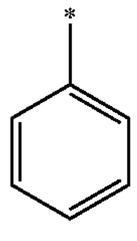


wherein in Formulae 4-1 to 4-5, 4-23, and 4-24 above

* is a binding site to a neighboring atom.

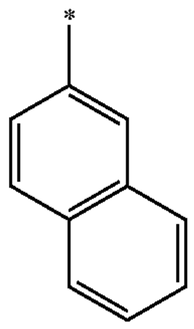
10. The organic light-emitting device of claim **1**, wherein R_{24} to R_{27} are each independently selected from Formulae 4-1 to 4-3, and 4-6 to 4-30 below:

4-1

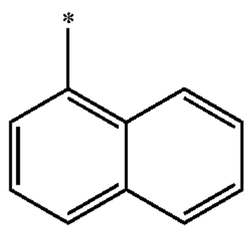


-continued

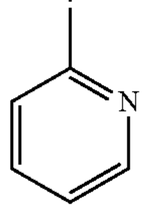
4-2



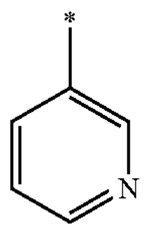
4-3



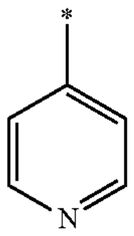
4-6



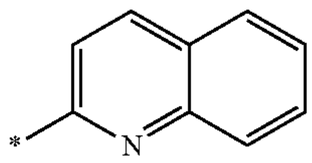
4-7



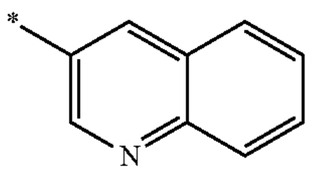
4-8



4-9



4-10



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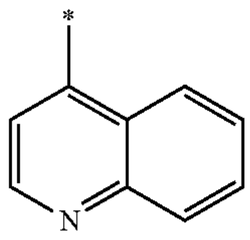

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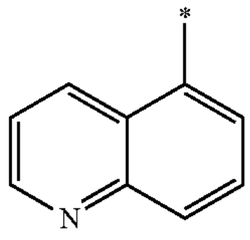

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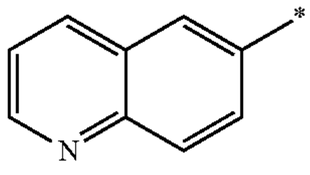

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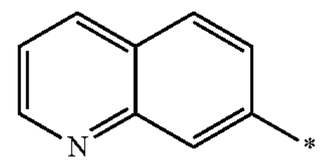

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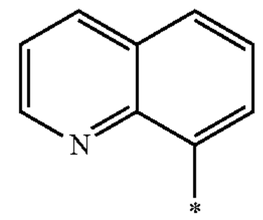

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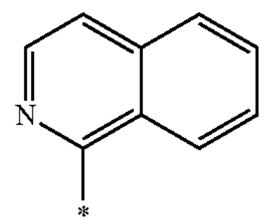

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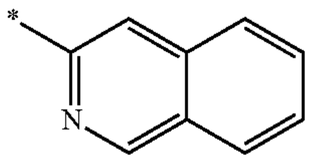

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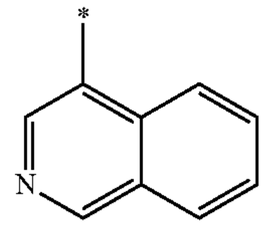

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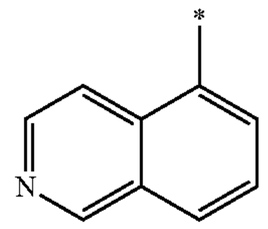

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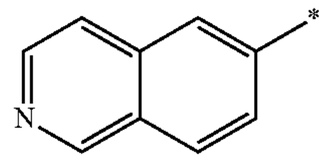

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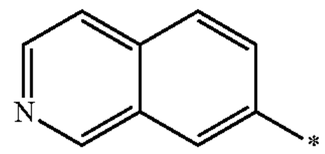

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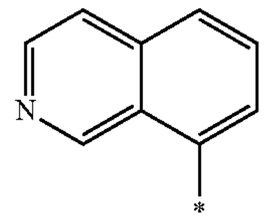

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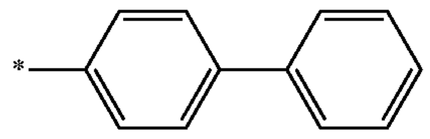

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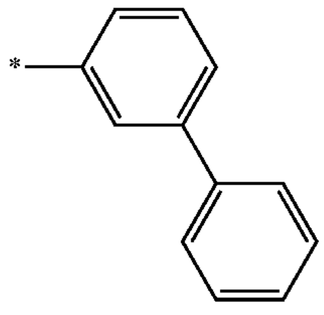

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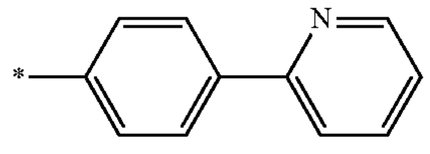

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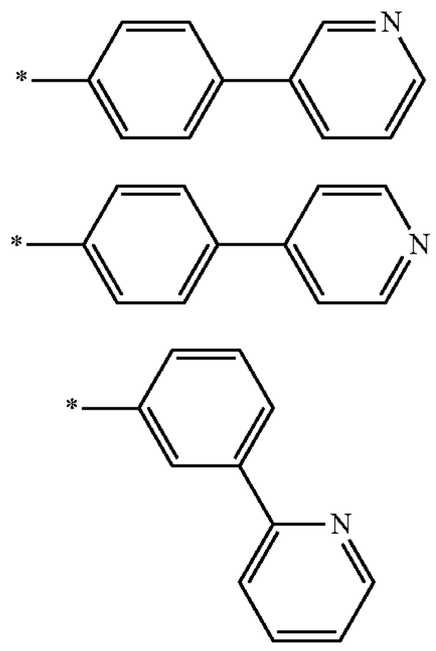
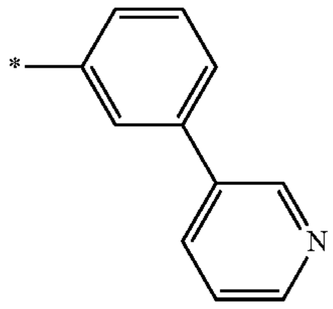
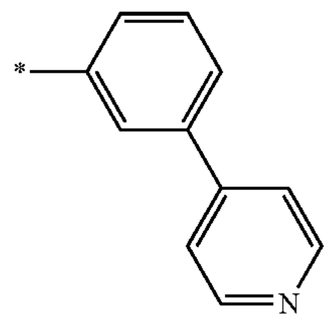






wherein in Formulae 4-1 to 4-3 and 4-6 to 4-30

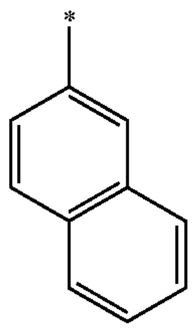
* is a binding site to a neighboring atom.

11. The organic light-emitting device of claim **1**, wherein R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, an n-hexyl group, an n-heptyl group, an n-octyl group, a phenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-fluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a carbazolyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a dibenzosilolyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group.

12. The organic light-emitting device of claim **1**, wherein R_{13}, R_{14}, R_{21} to R_{23}, and R_{28} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, an n-pentyl group, an n-hexyl group, an n-heptyl group, an n-octyl group, and groups represented by Formula 4-1 to 4-30:

4-1

4-2



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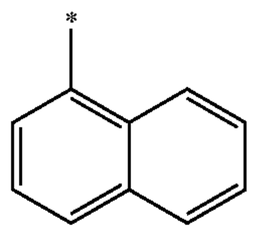

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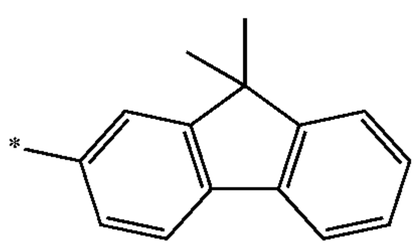

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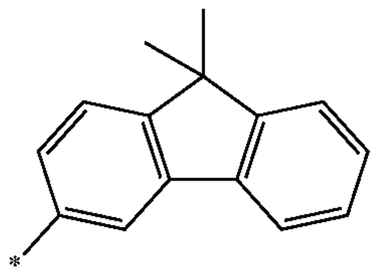

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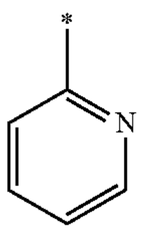

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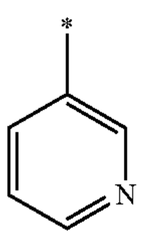

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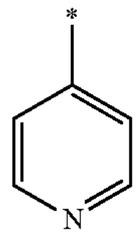

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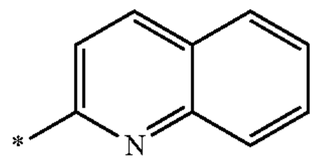

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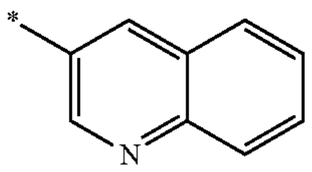

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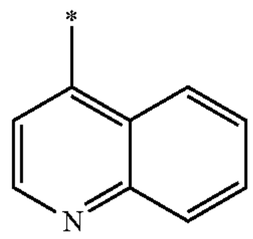

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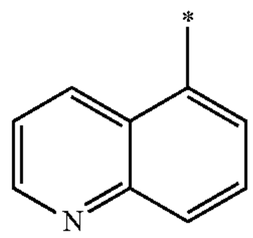

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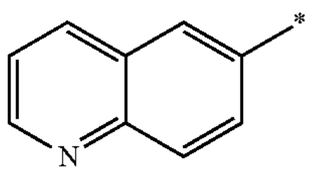

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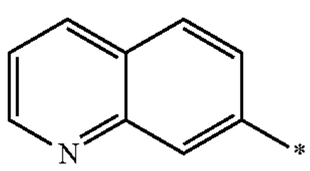

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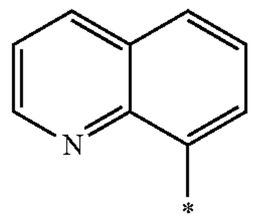

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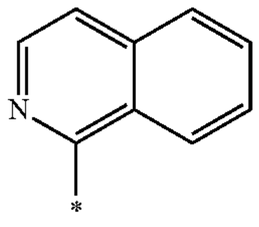

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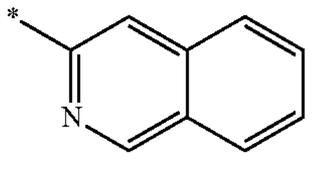

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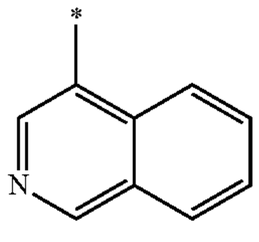

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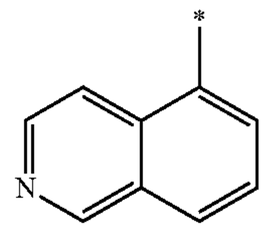

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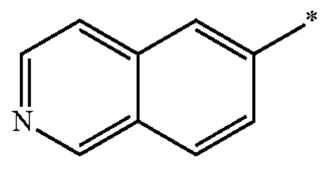

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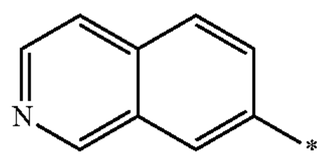

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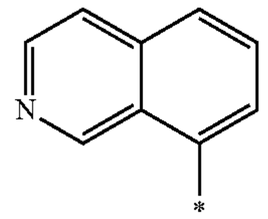

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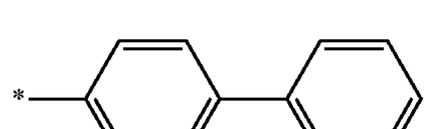

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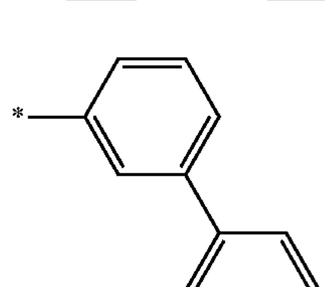

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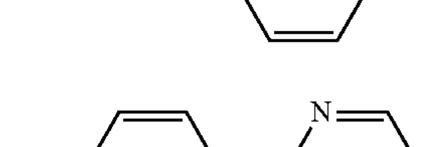
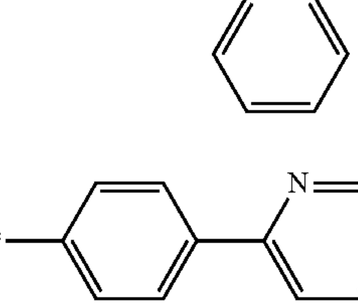


4-26

4-27

4-28

4-29



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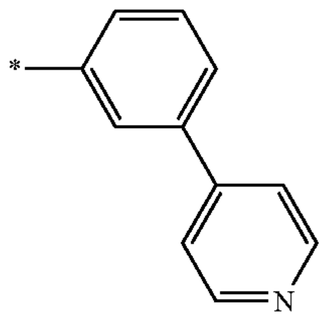
4-30

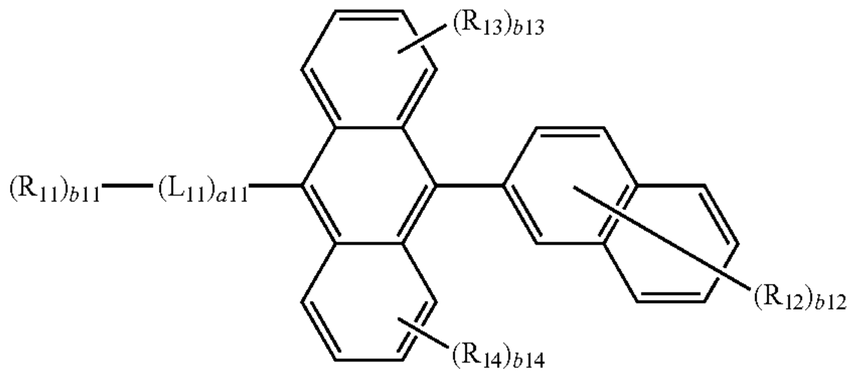


wherein in Formulae 4-1 to 4-30

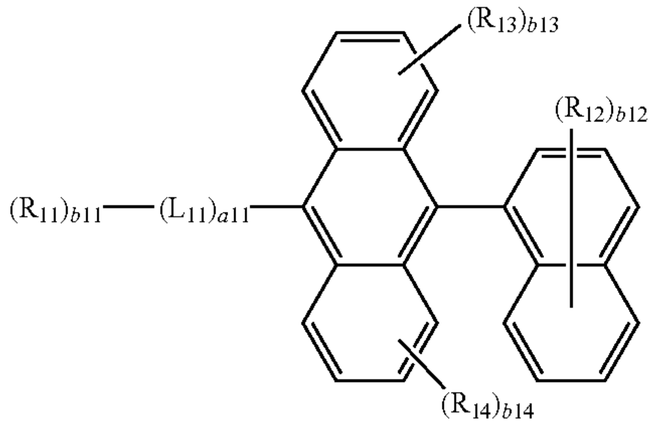
* is a binding site to a neighboring atom.

13. The organic light-emitting device of claim **1**, wherein the at least one first material is represented by any one of Formulae 1A and 1B, and the at least one second material is represented by any one of Formulae 2A to 2C below:

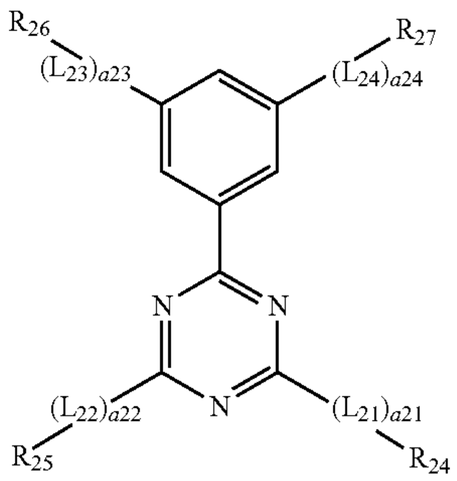
Formula 1A



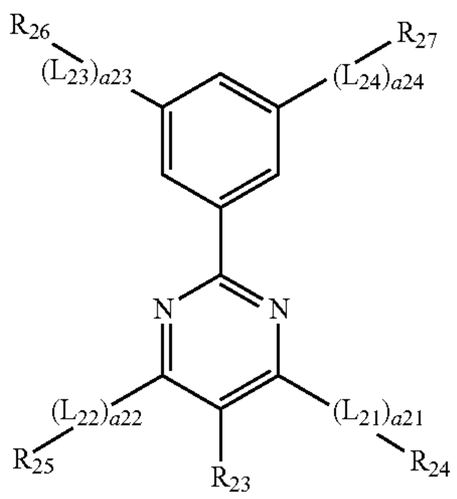
Formula 1B



Formula 2A



Formula 2B



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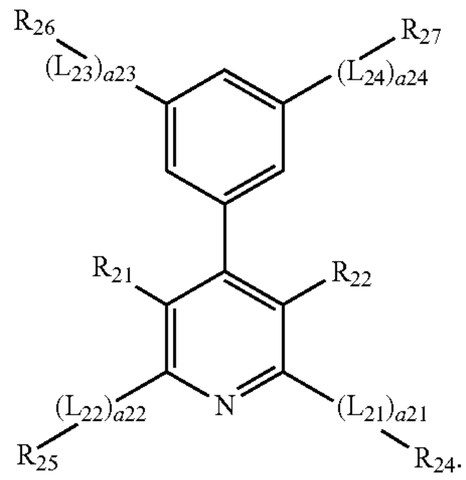
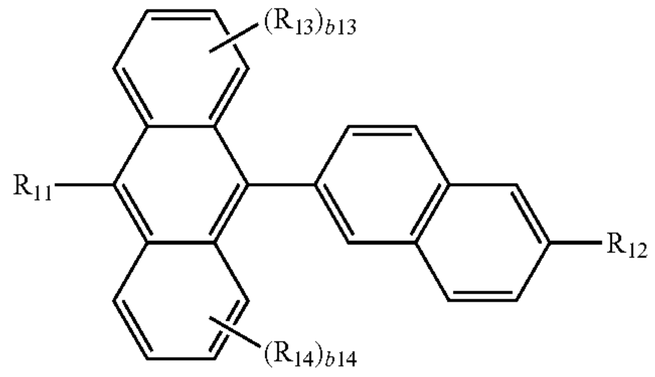
Formula 2C

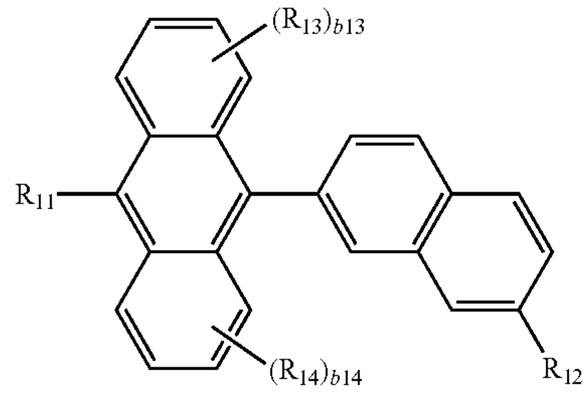


14. The organic light-emitting device of claim **1**, wherein the at least one first material is represented by any one of Formulae 1A-1, 1A-2, 1B-1, and 1B-2, and the at least one second material is represented by any one of Formulae 2A-1 to 2C-1:

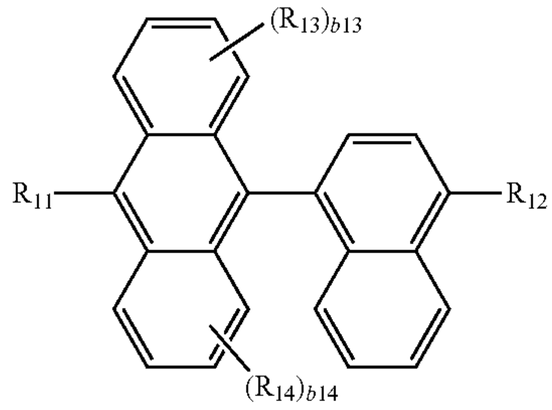
Formula 1A-1



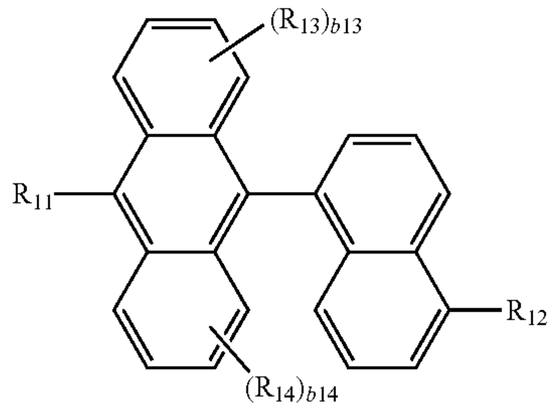
Formula 1A-2



Formula 1B-1



Formula 1B-2



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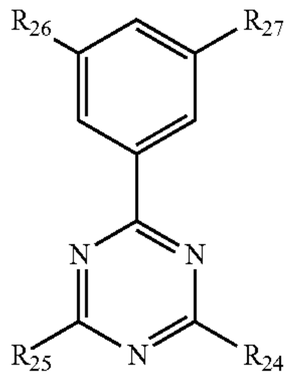
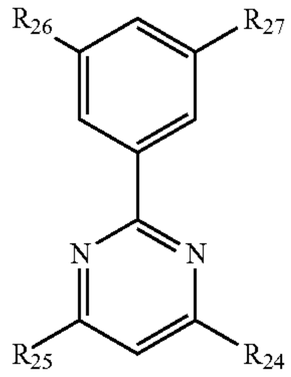
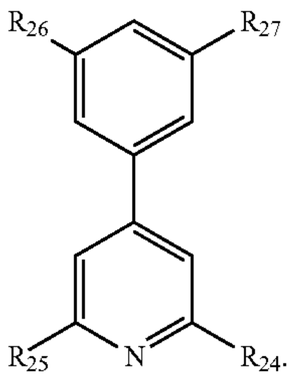
Formula 2A-1



Formula 2B-1

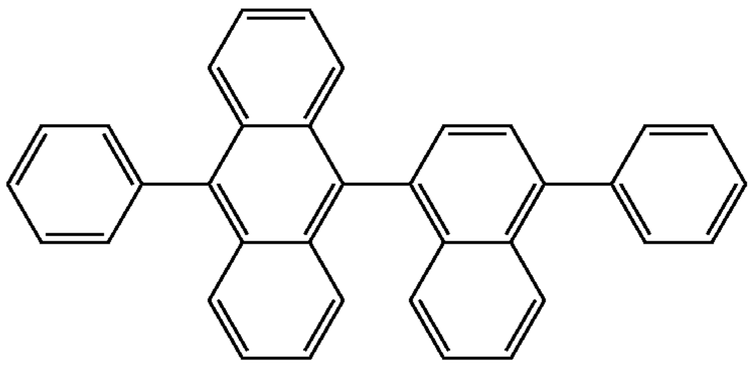


Formula 2C-1

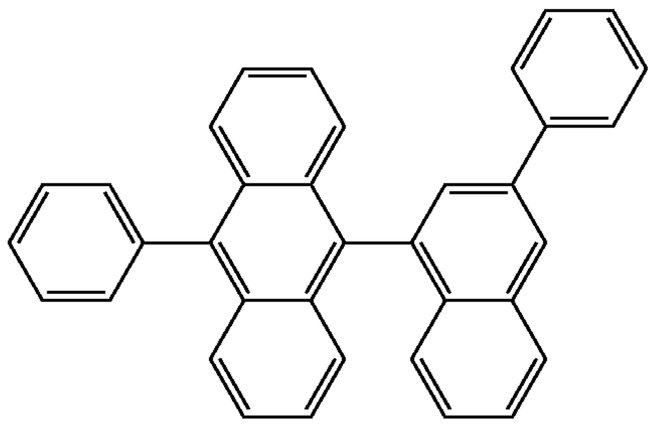


15. The organic light-emitting device of claim **1**, wherein the at least one first material is selected from Compounds 100 to 201 below, and the at least one second material is selected from Compounds 300 to 544 below:

100



101



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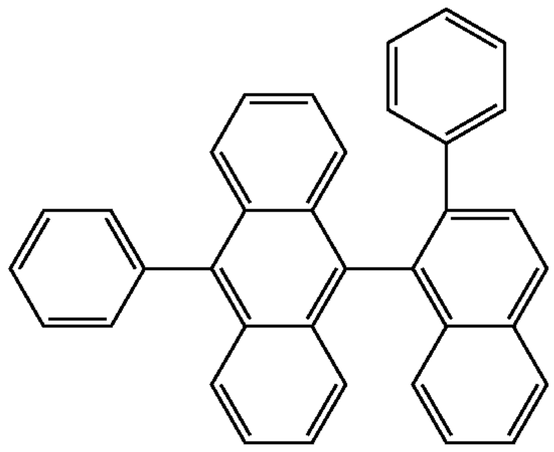
102



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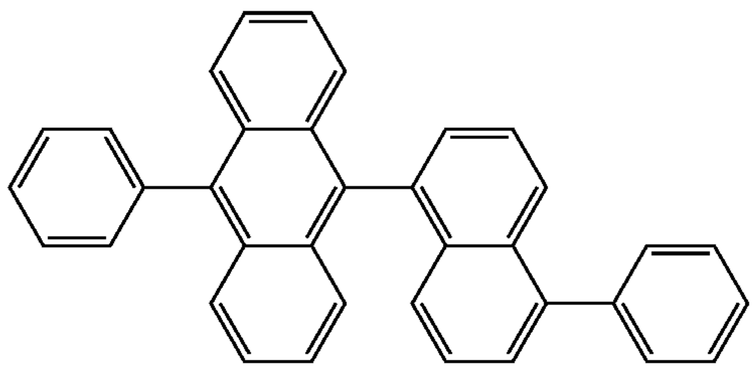

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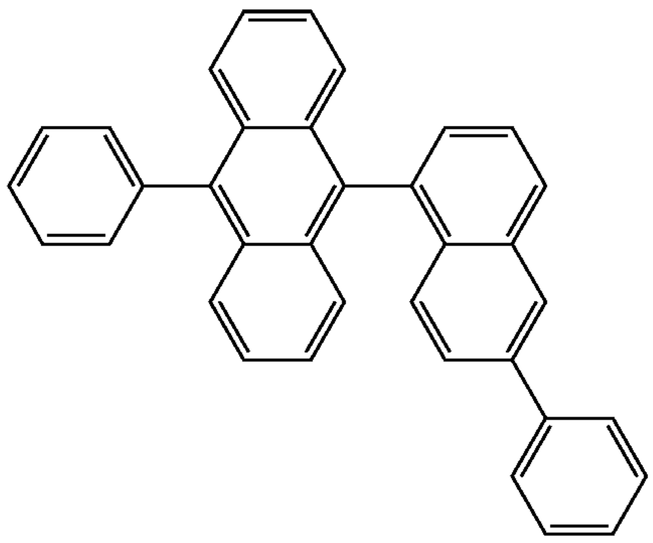

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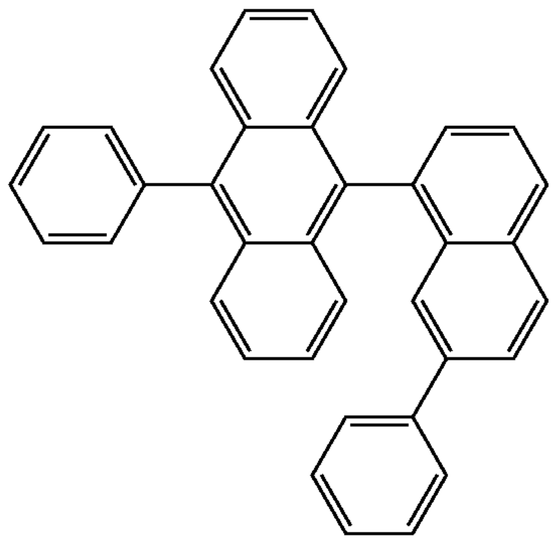

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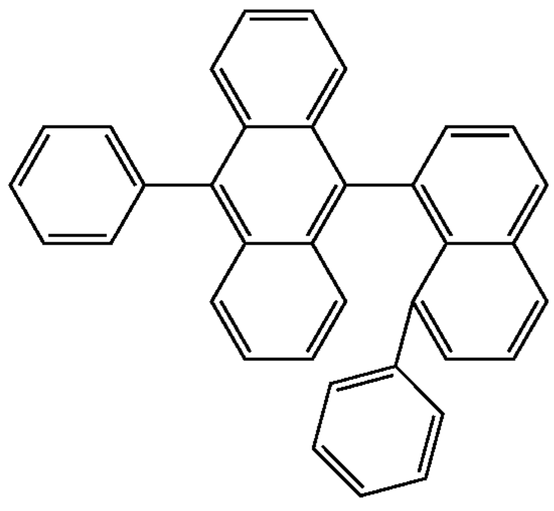

187

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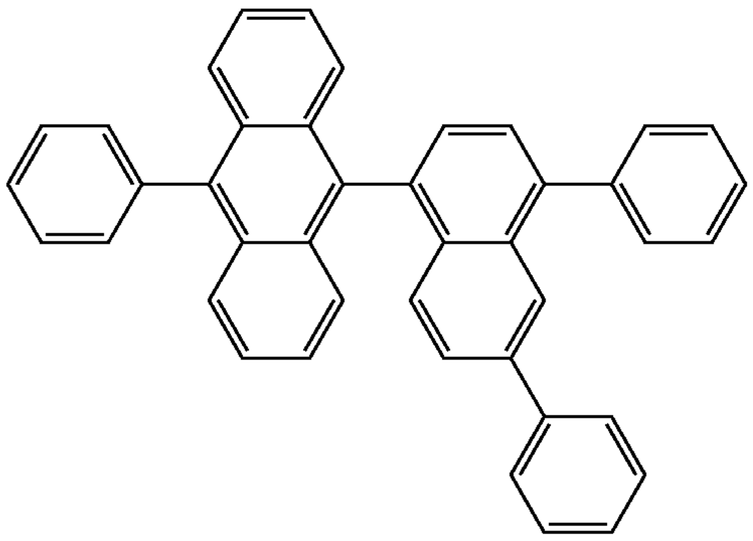
107



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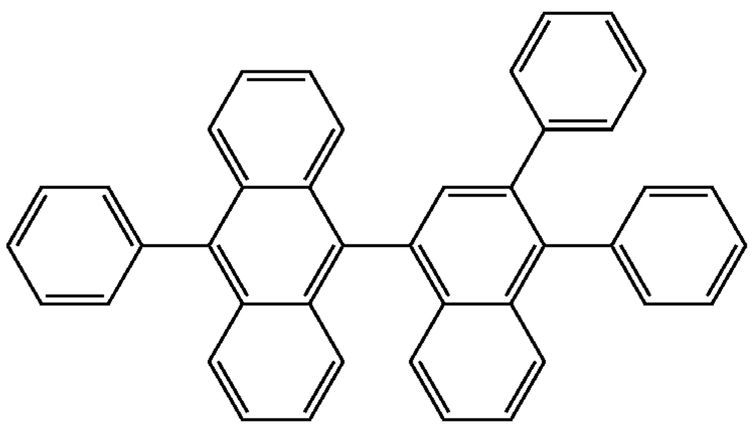

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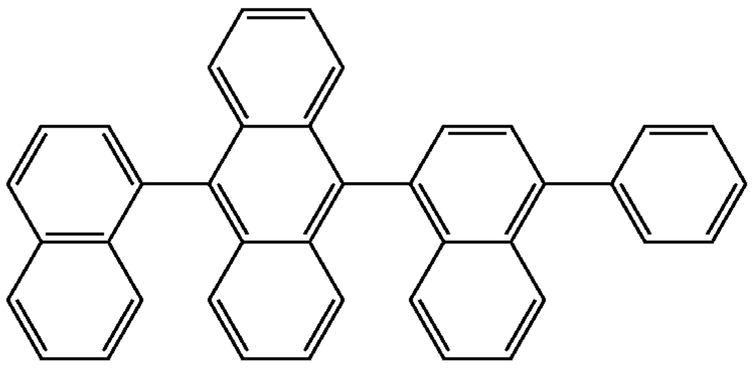

110

111

188

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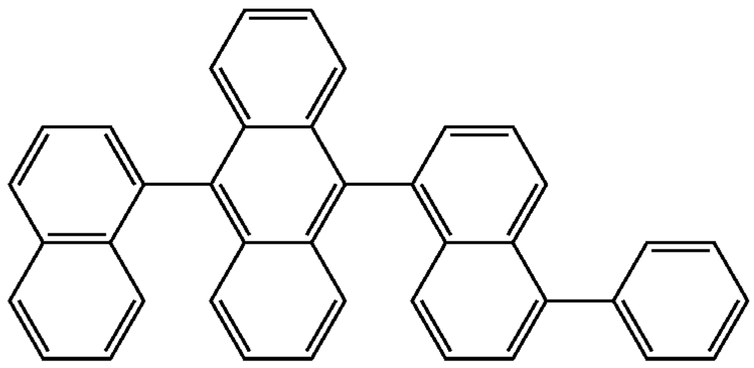
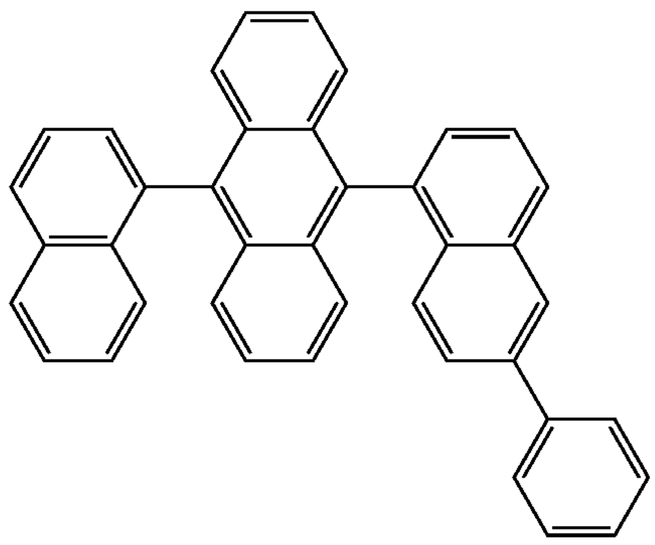
112



113



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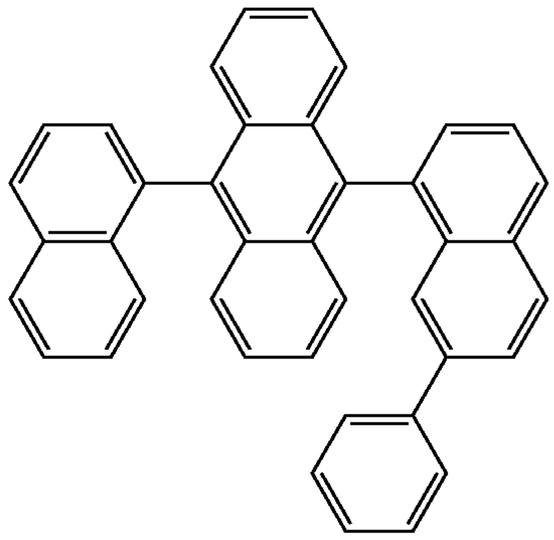

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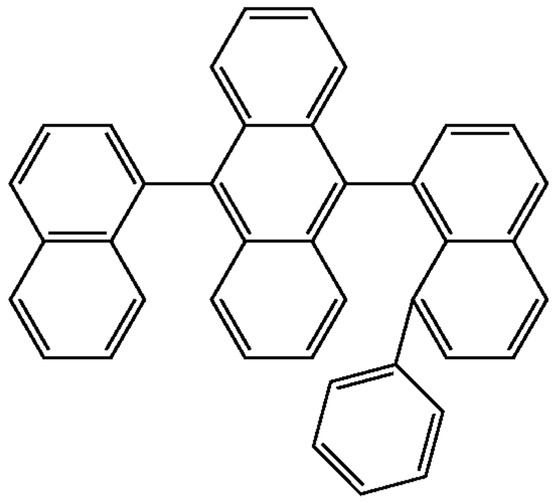

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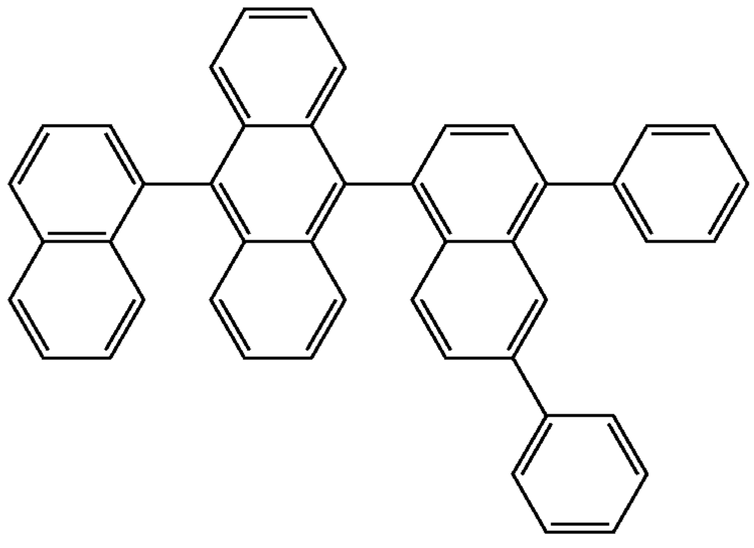

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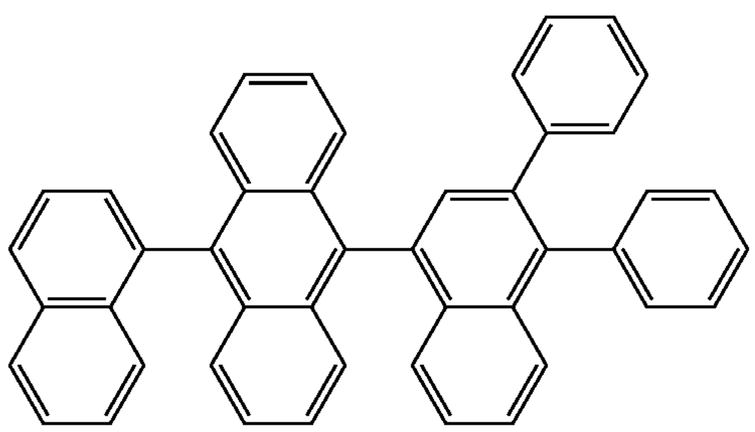
117



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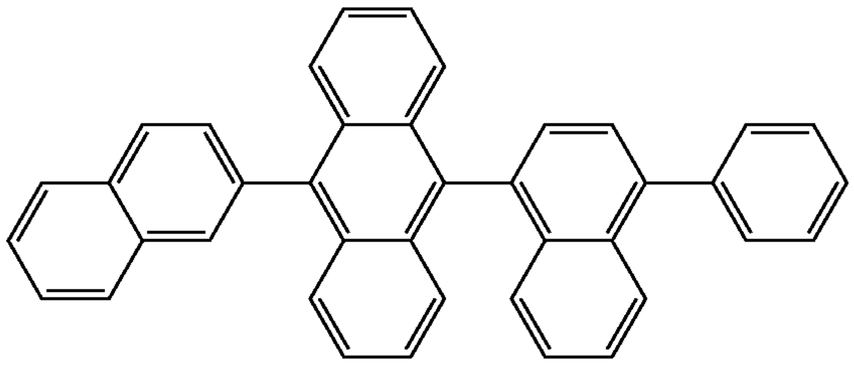

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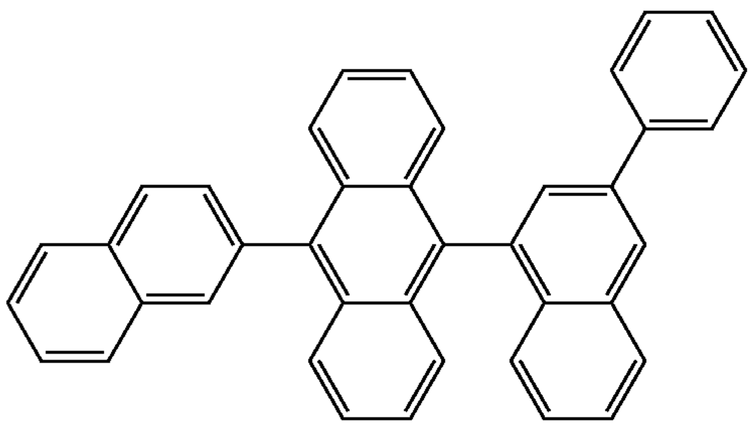

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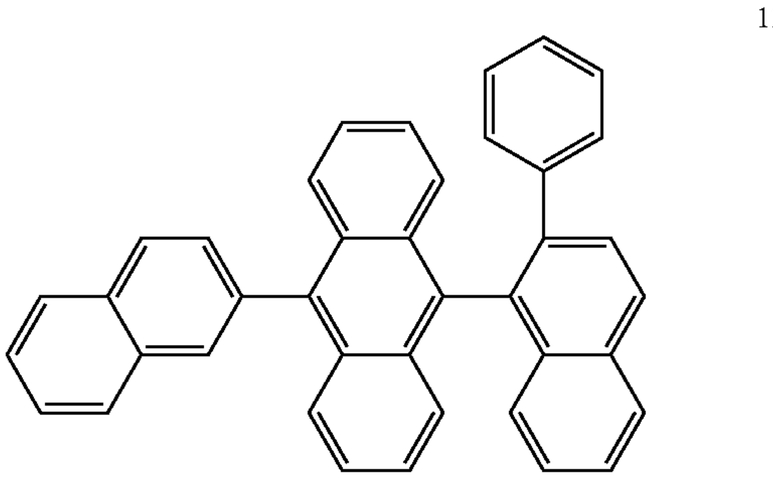

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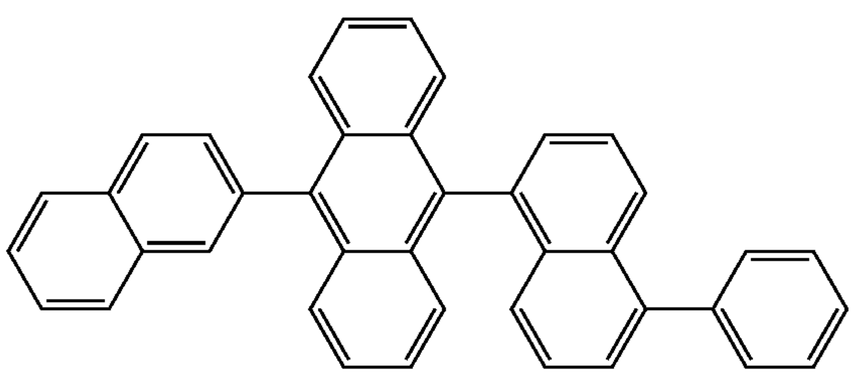

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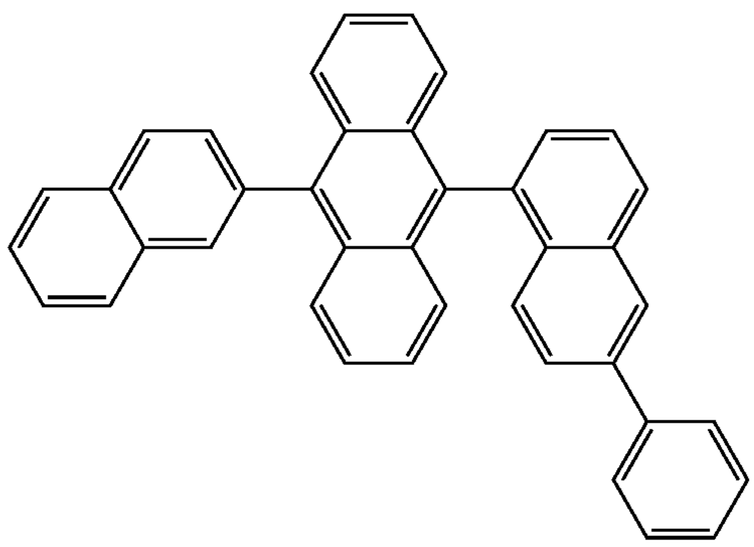

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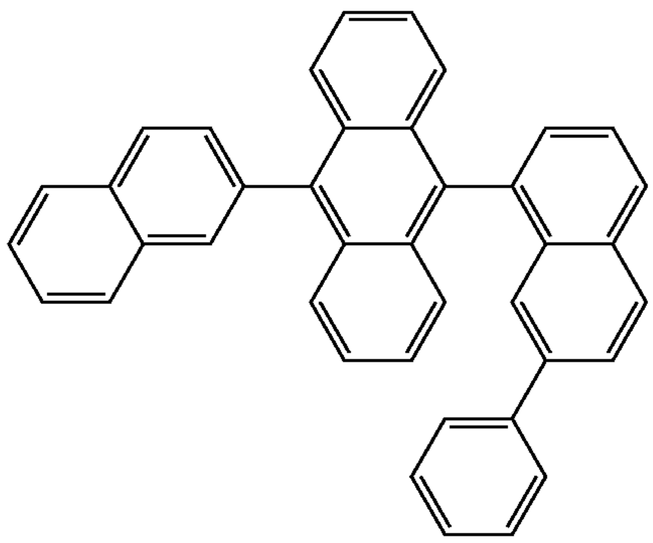

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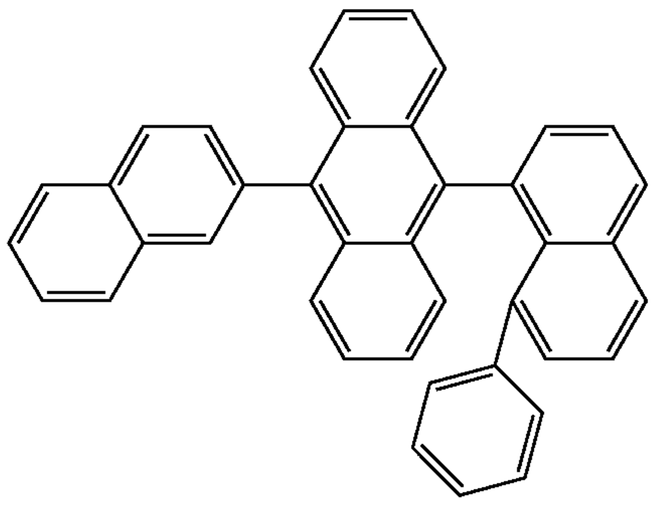

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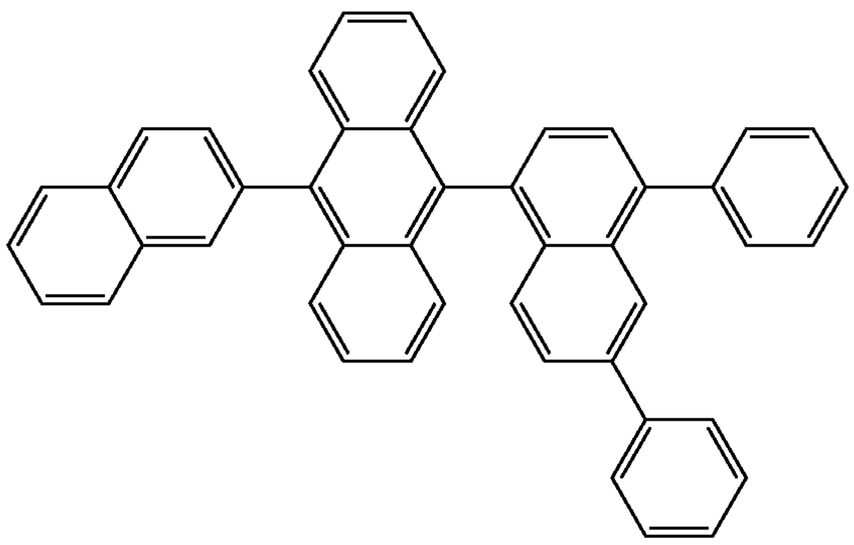

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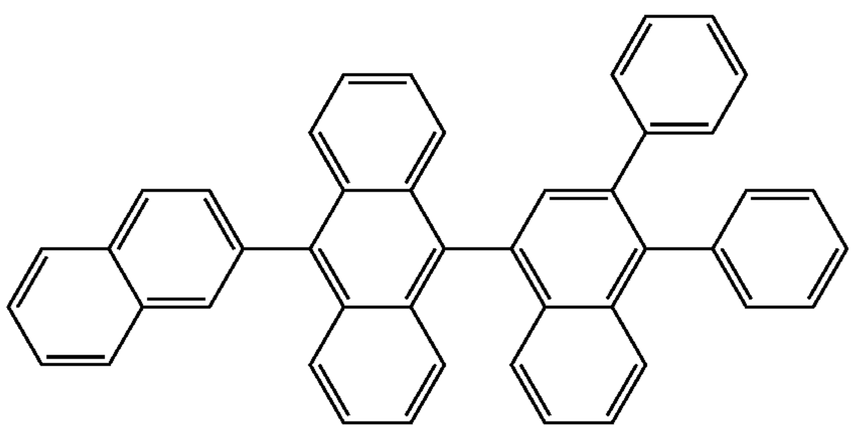
126



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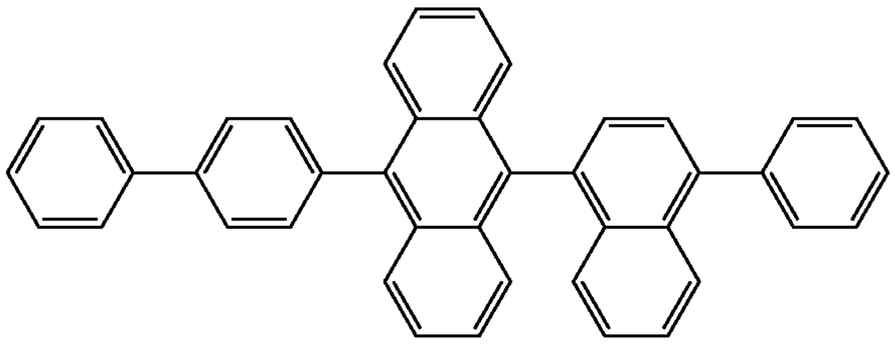

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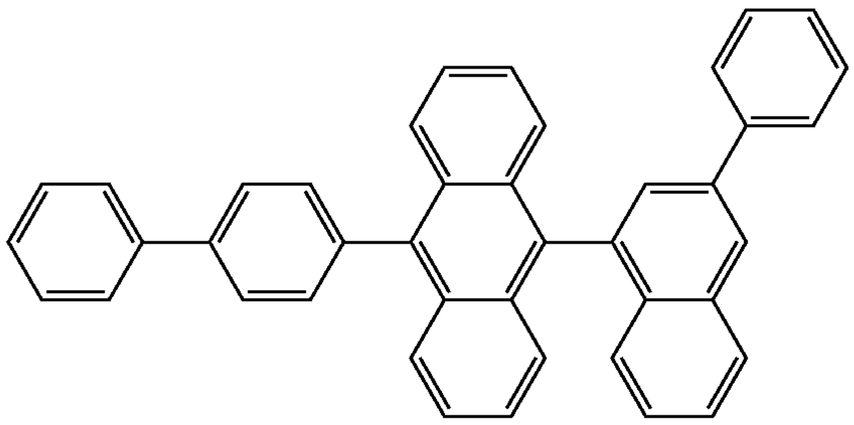

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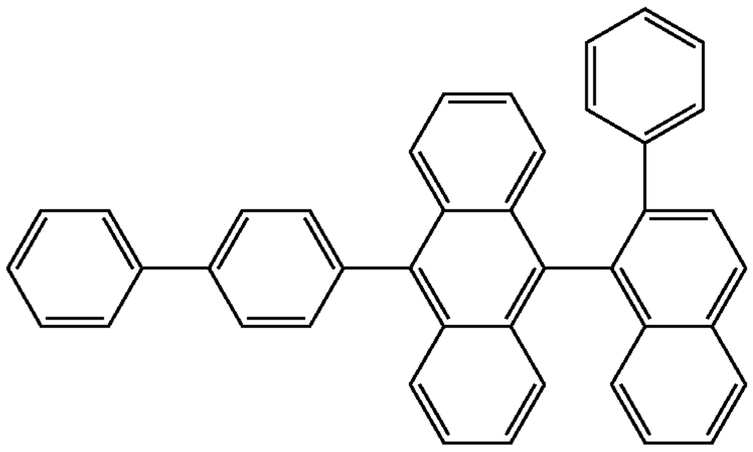

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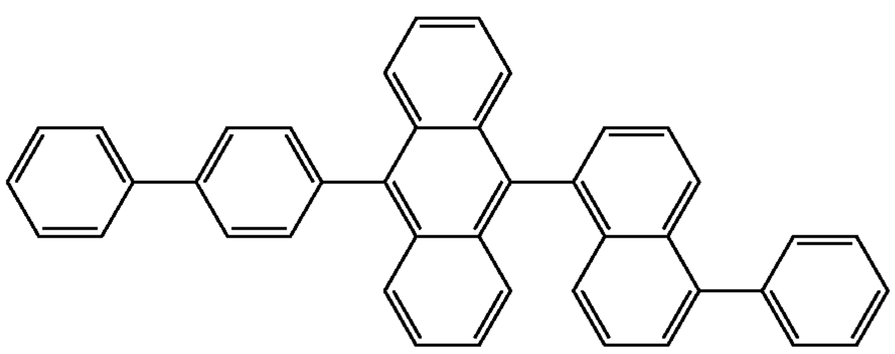

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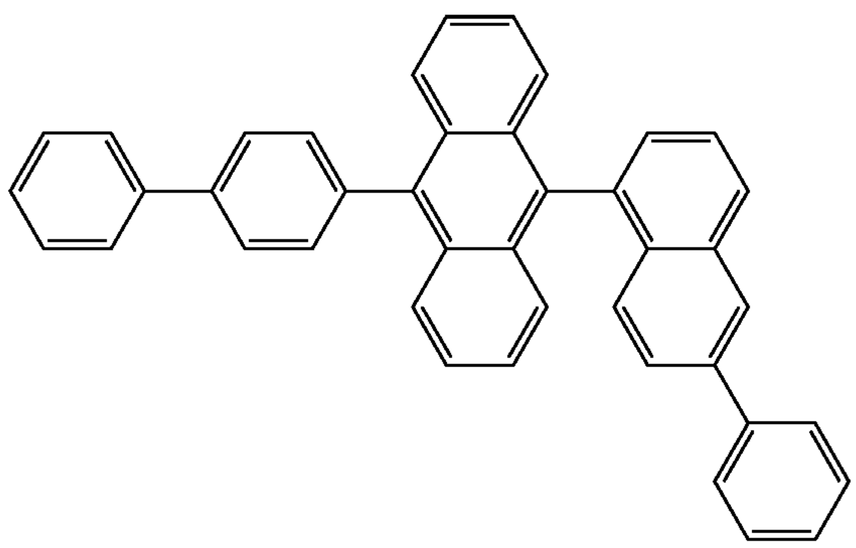

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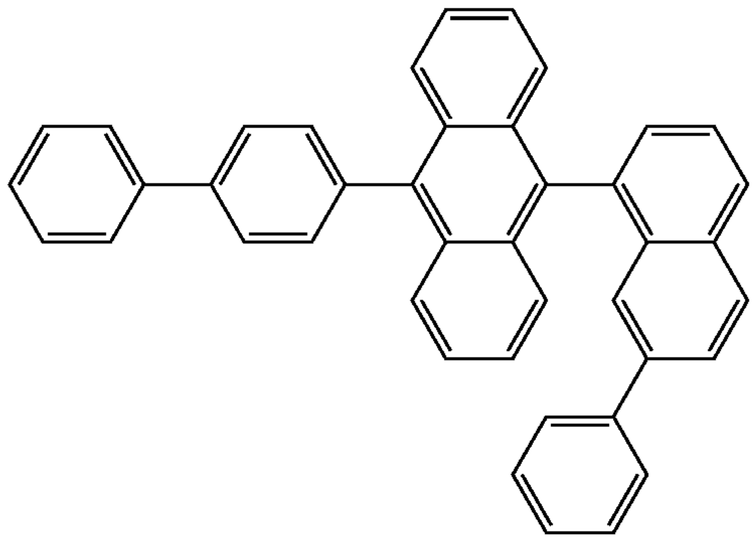

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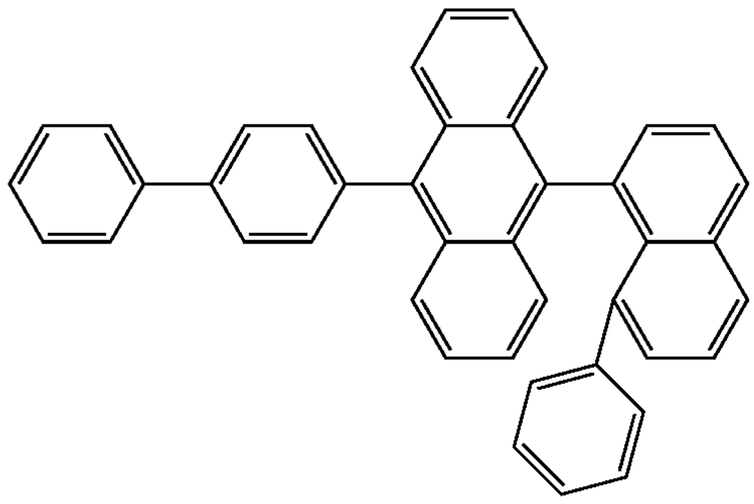

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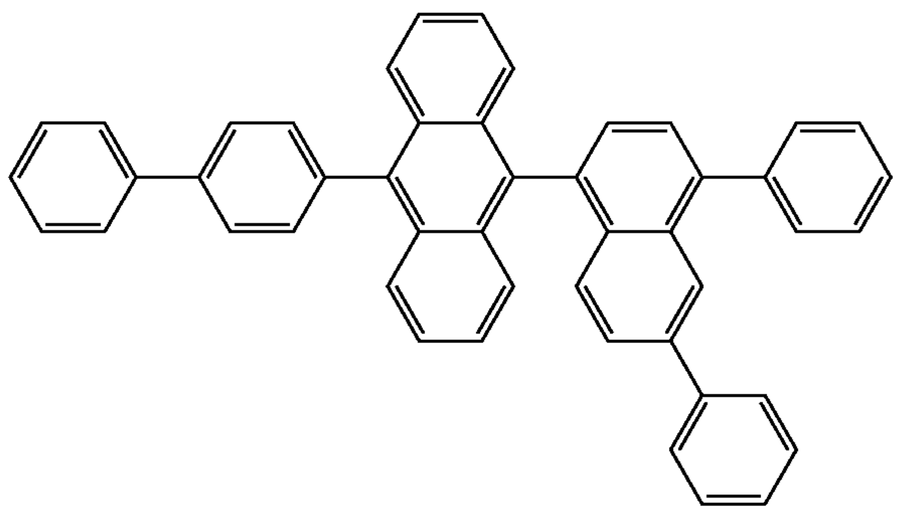

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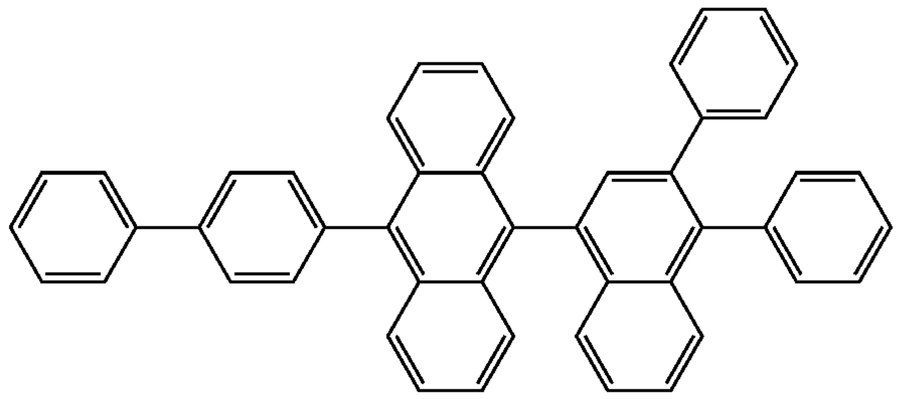
135



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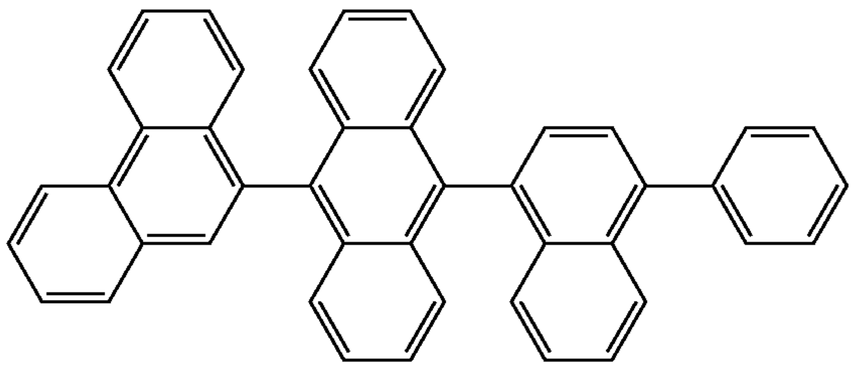

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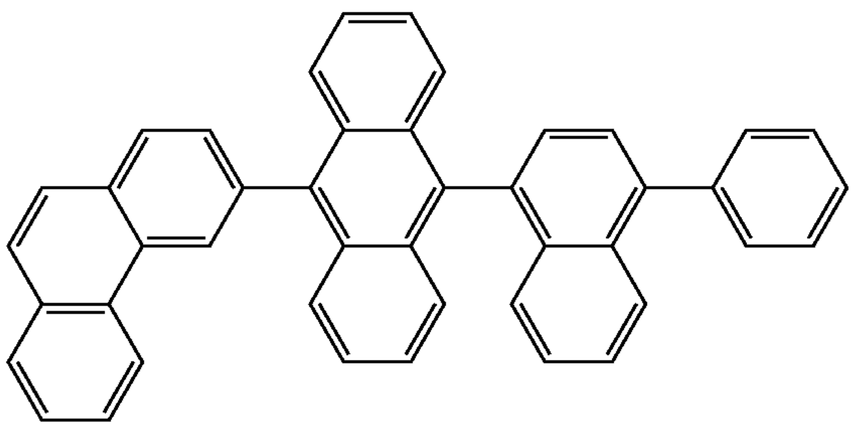

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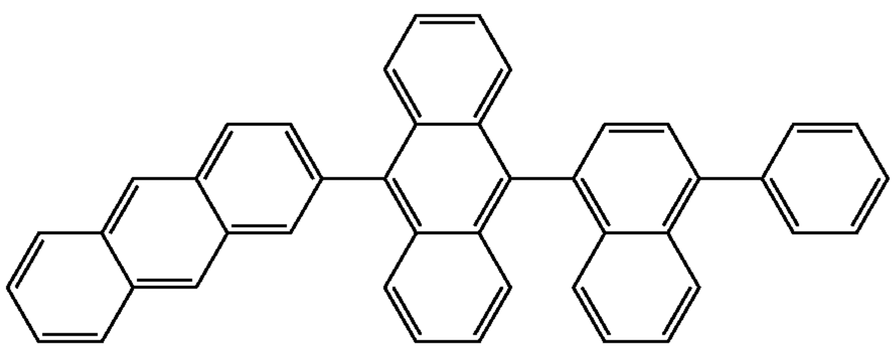

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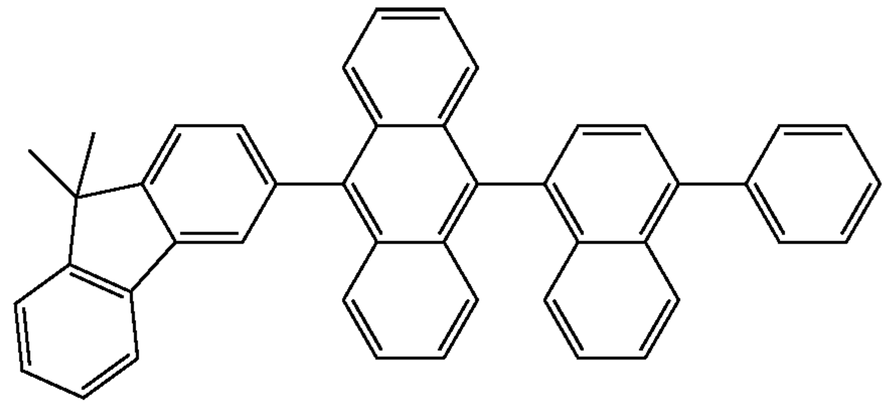

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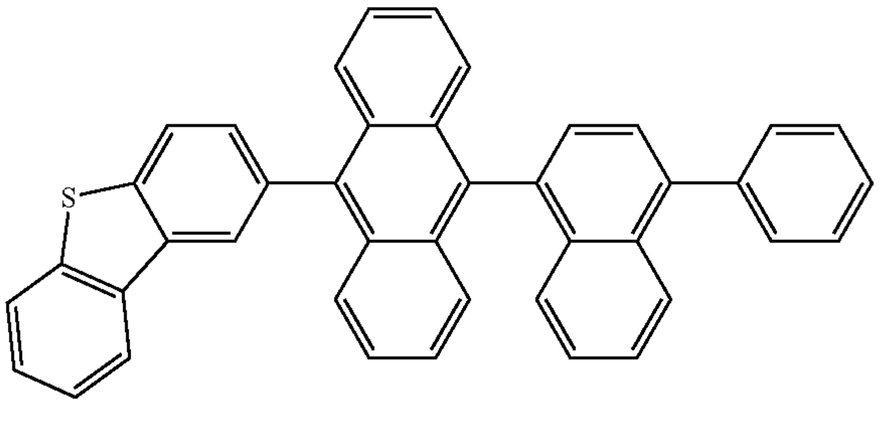

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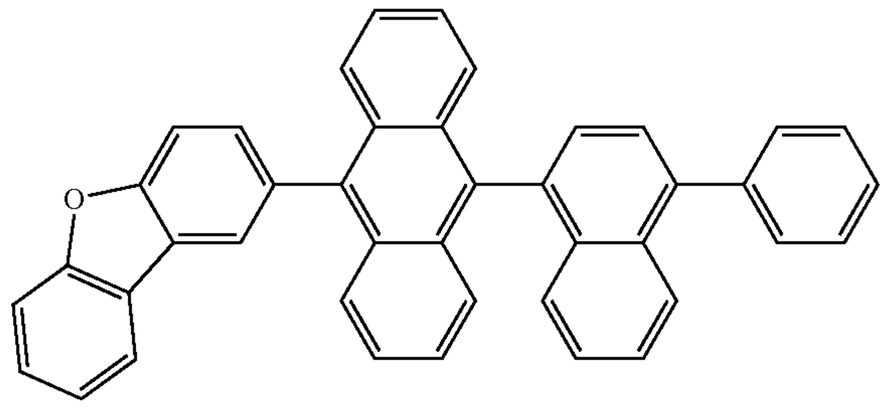
141



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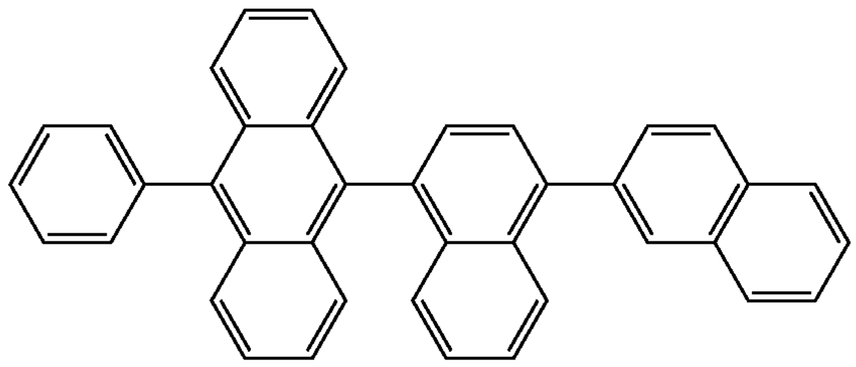

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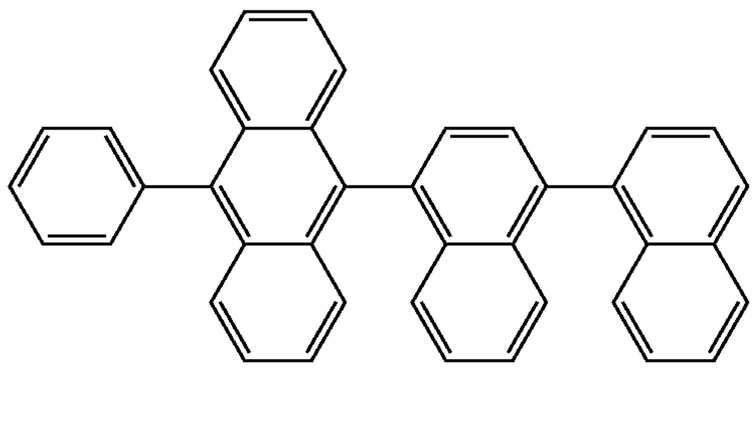

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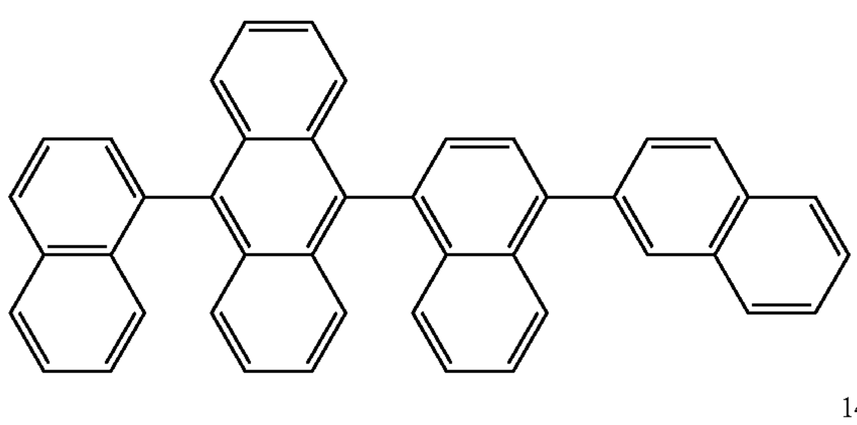
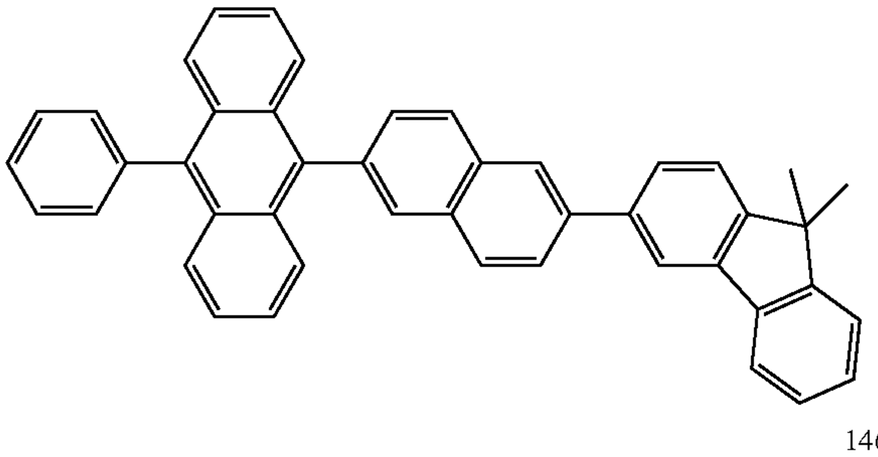
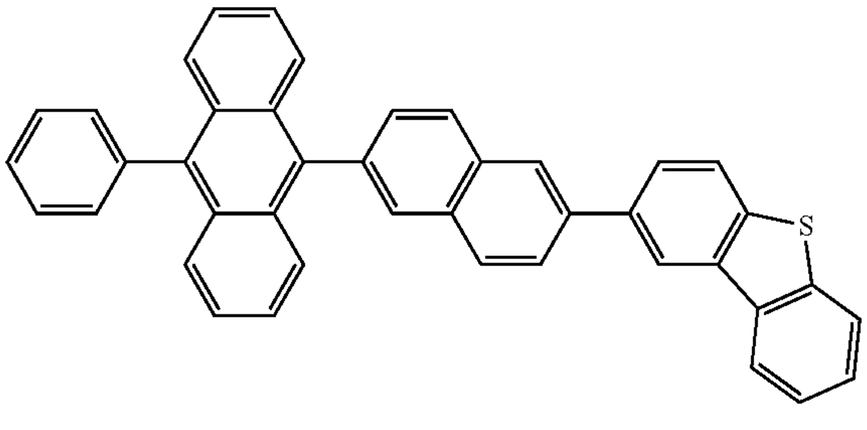


145



146



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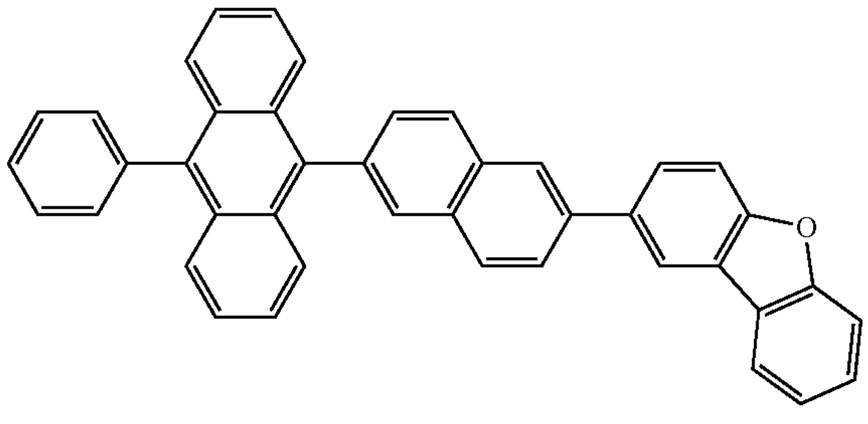
147



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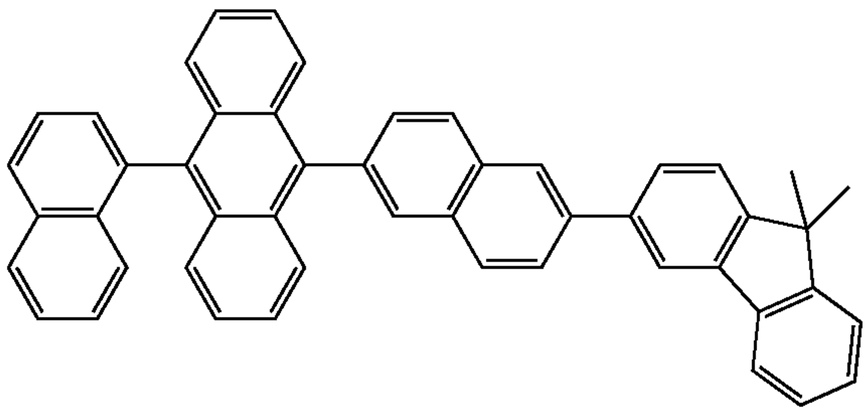
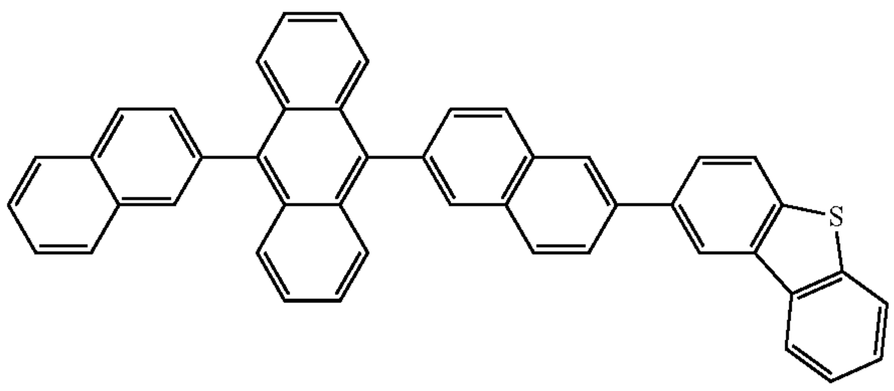


149



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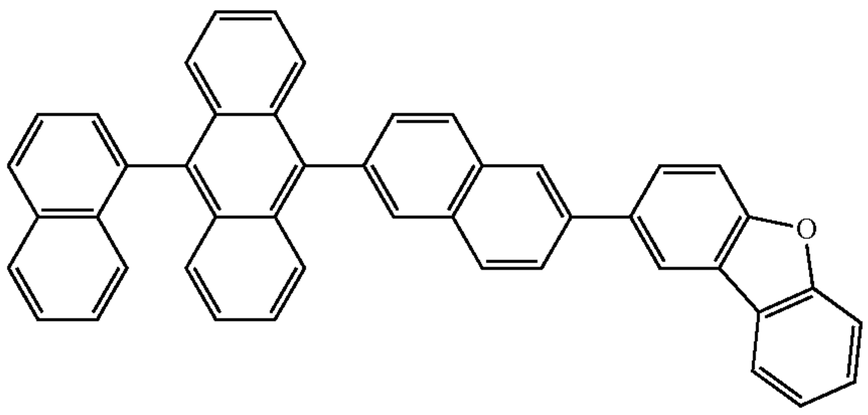
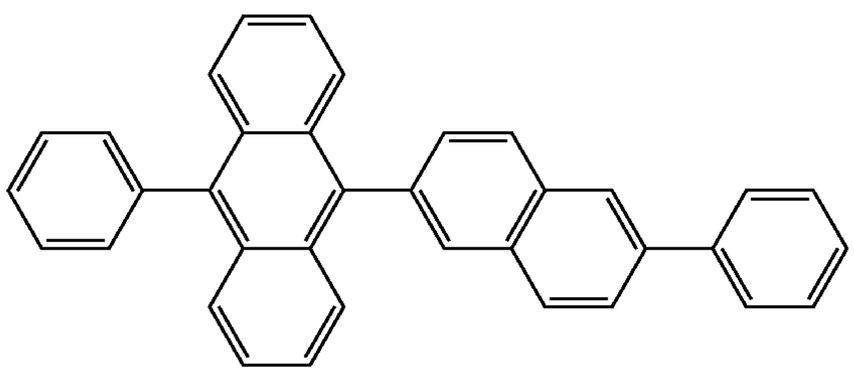


151



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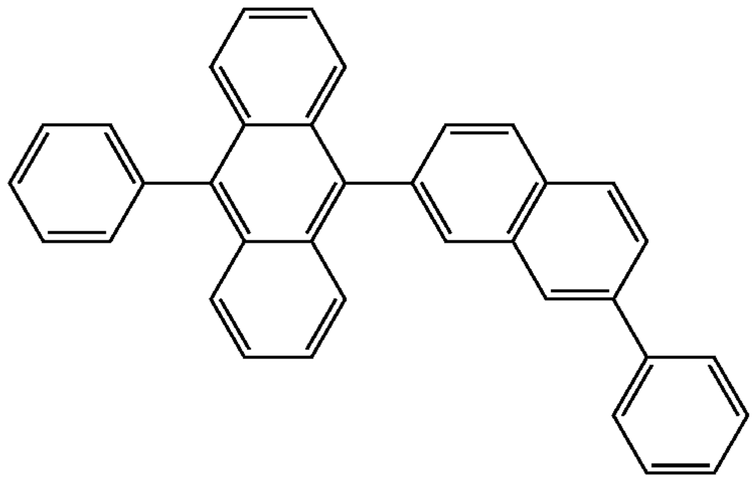
152



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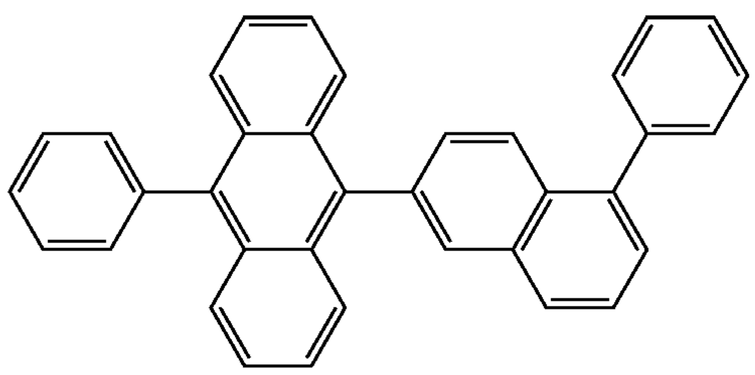

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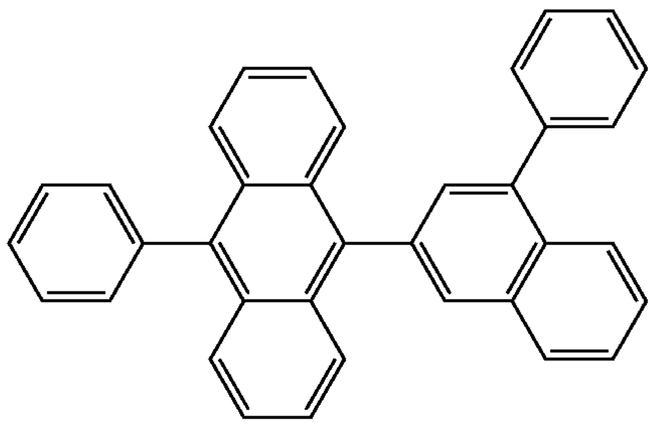

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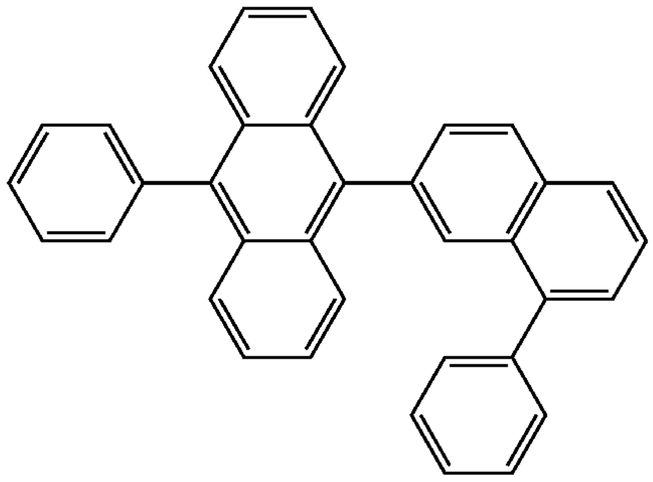

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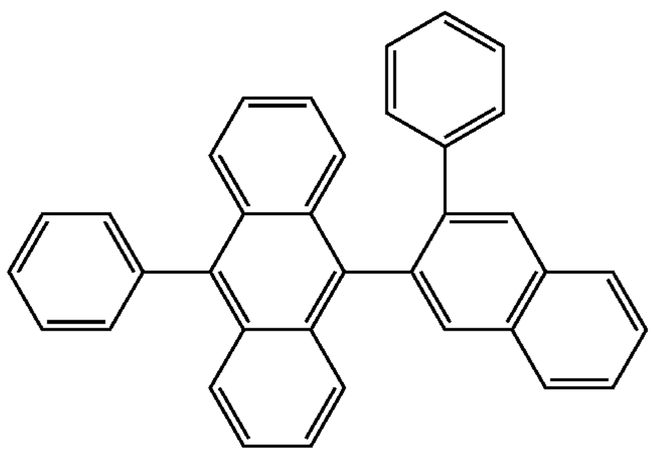

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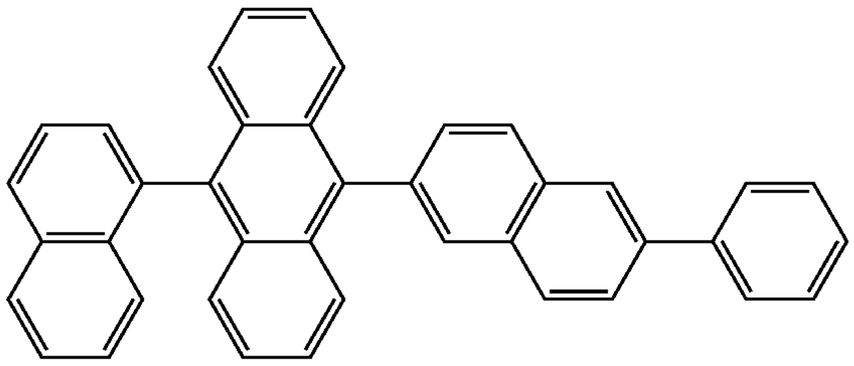

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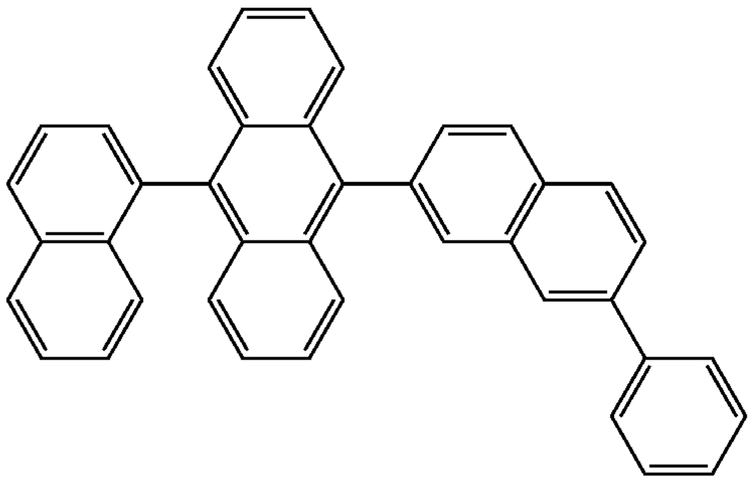

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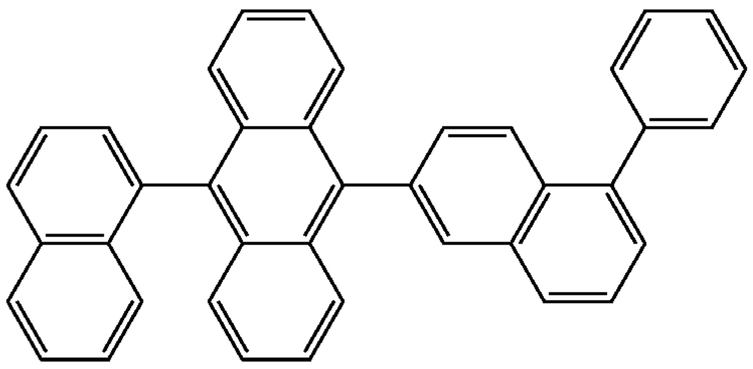

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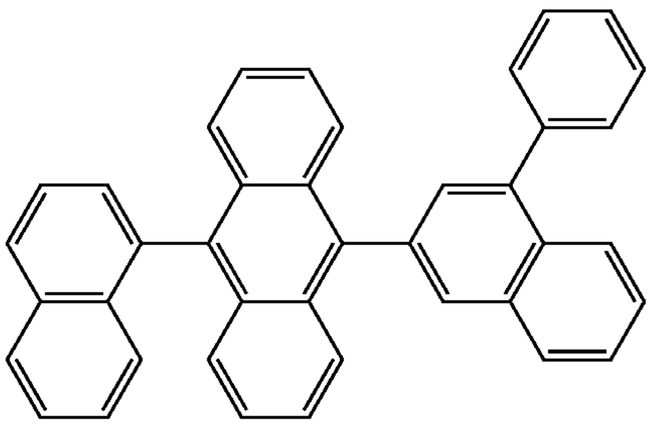

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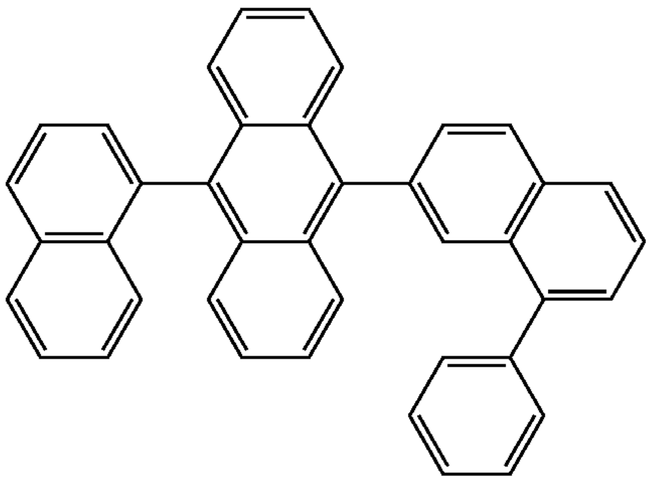

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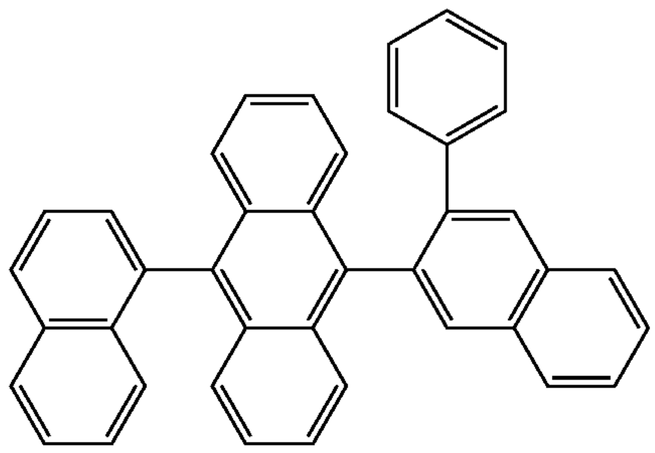

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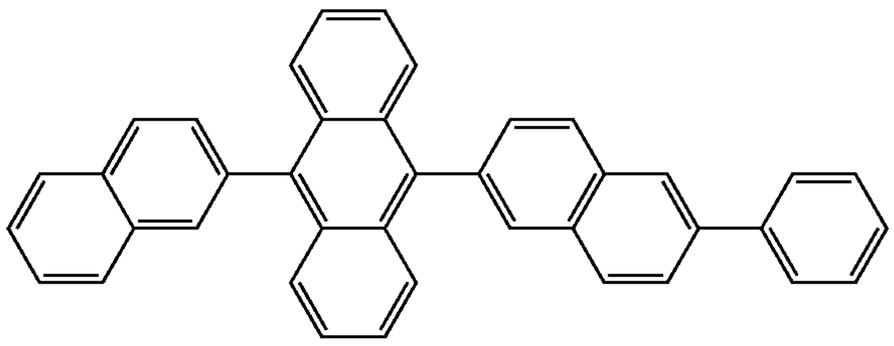

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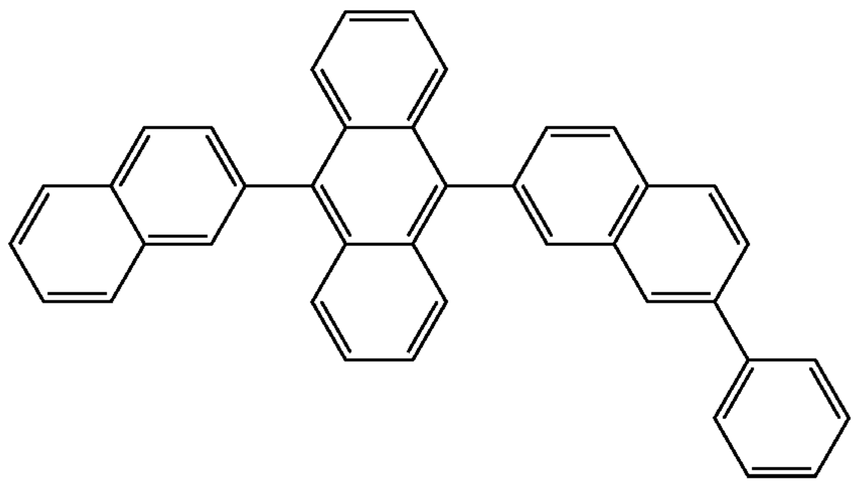

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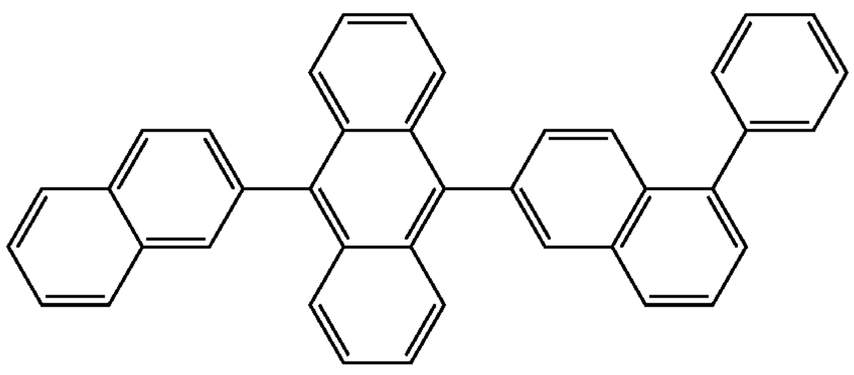

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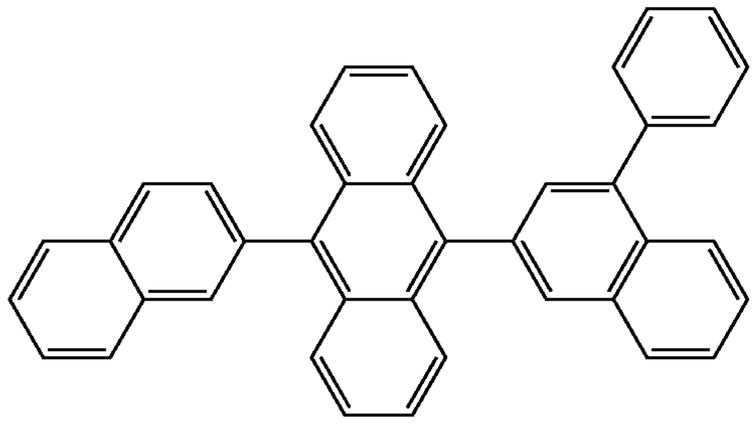

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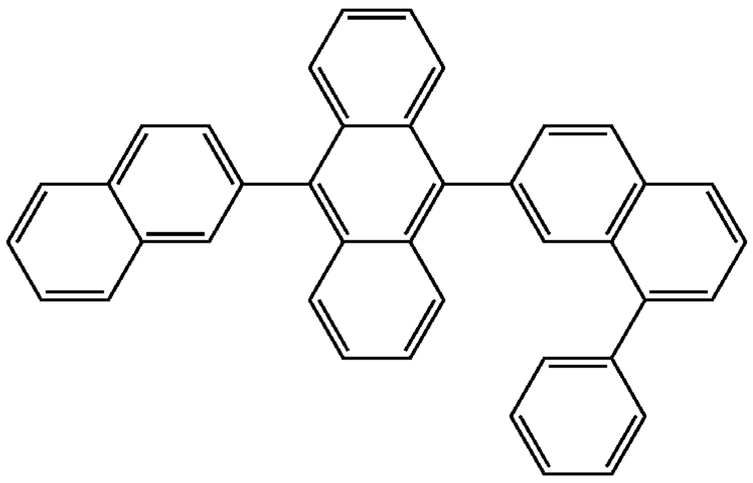

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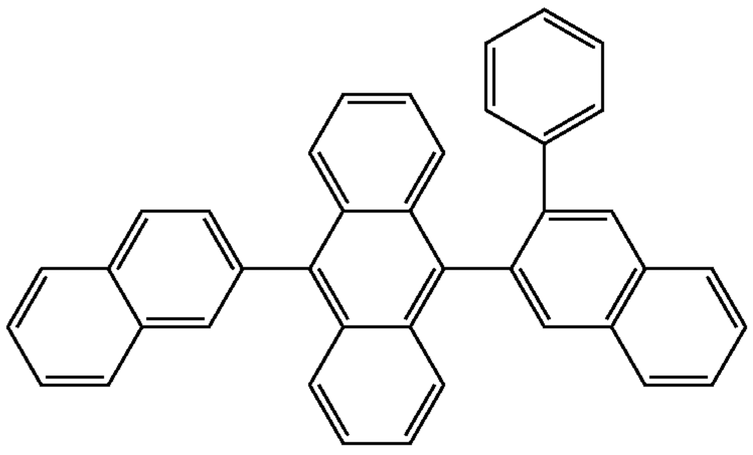

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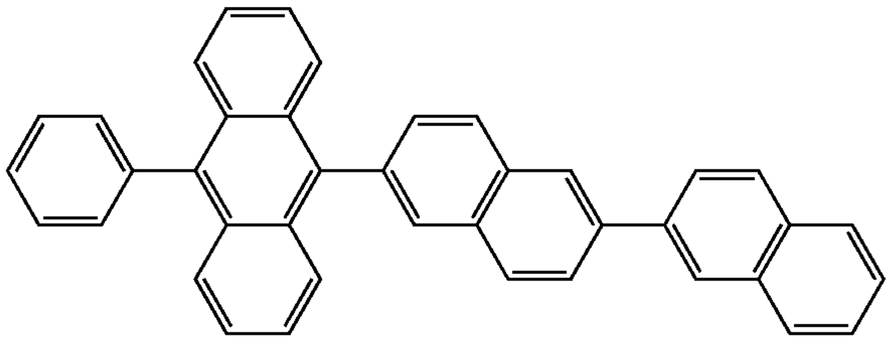

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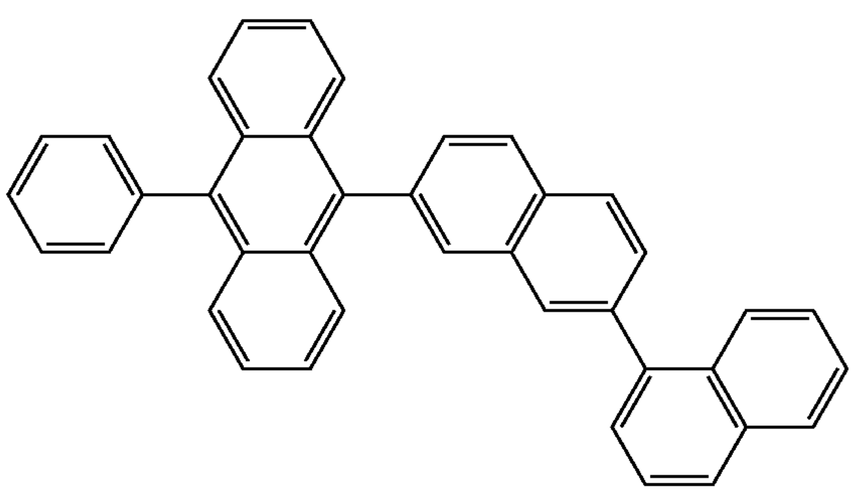

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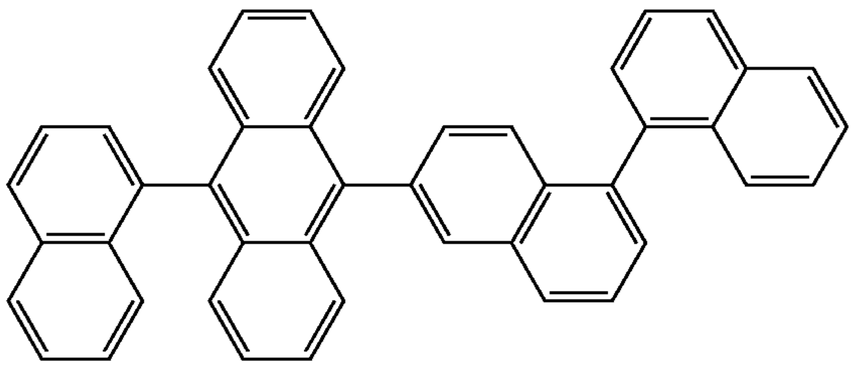

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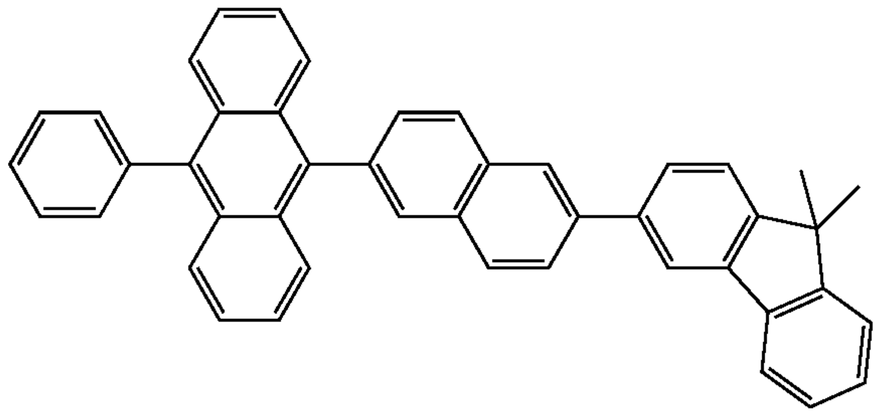

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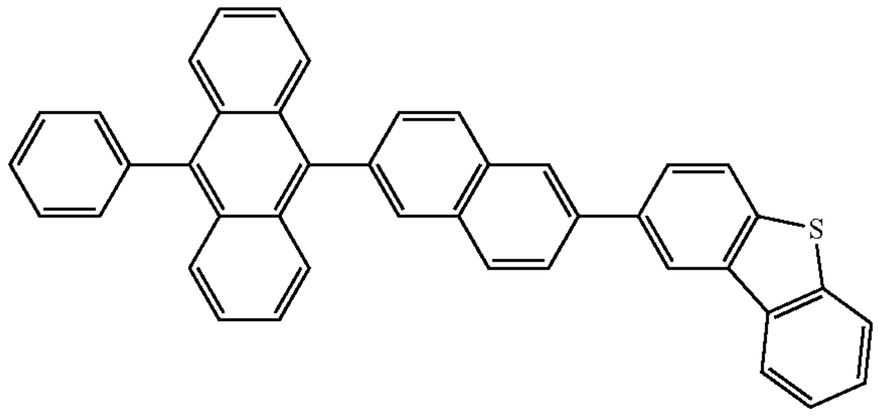

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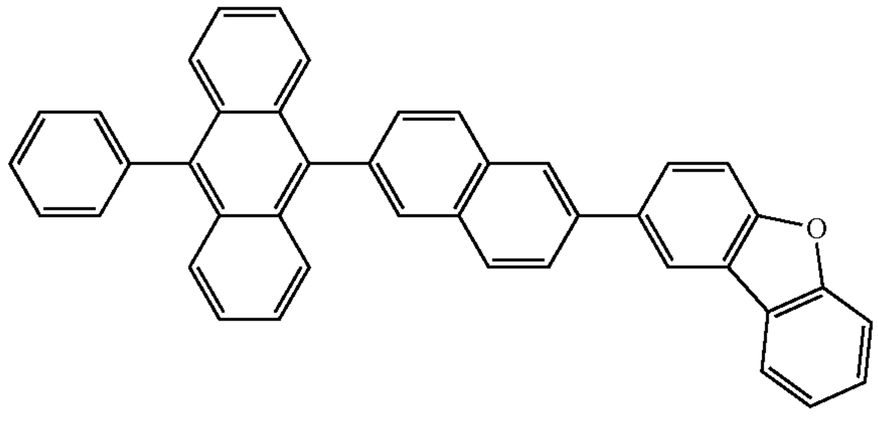

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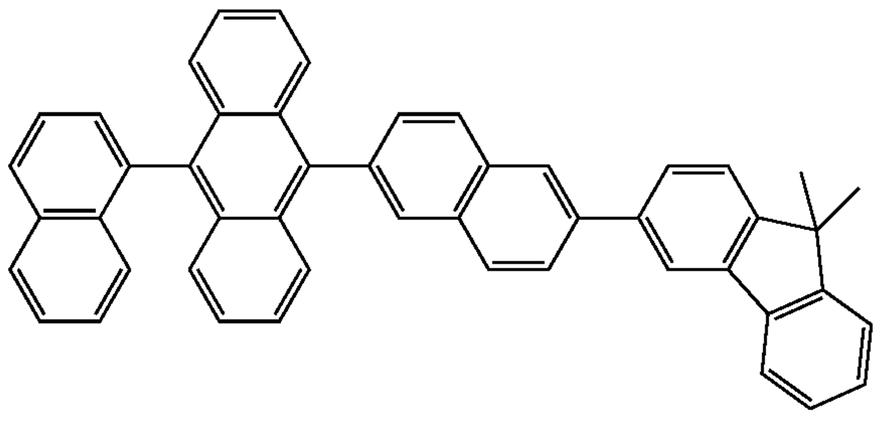

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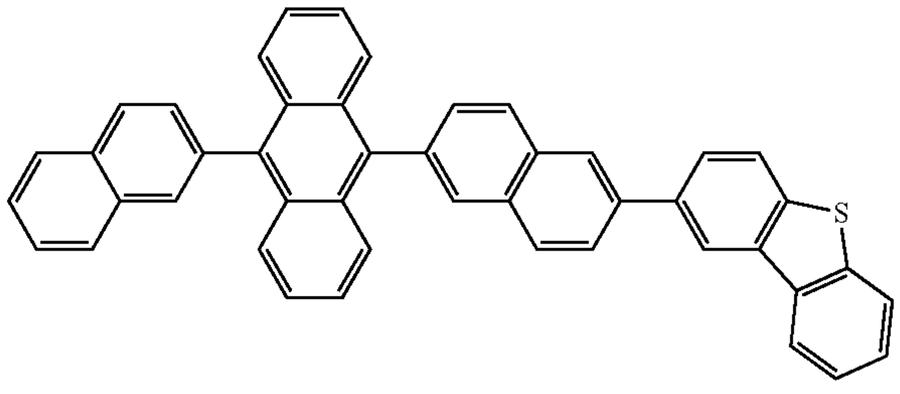

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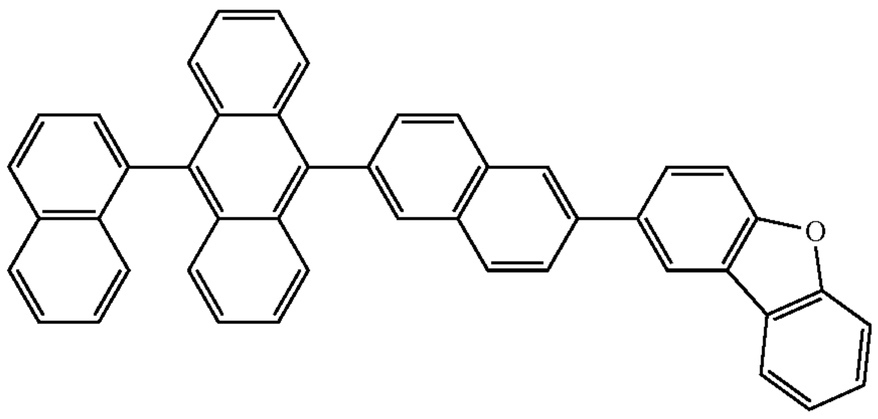

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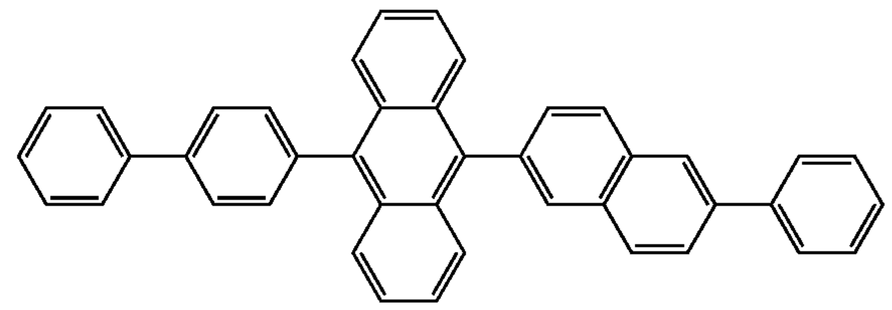

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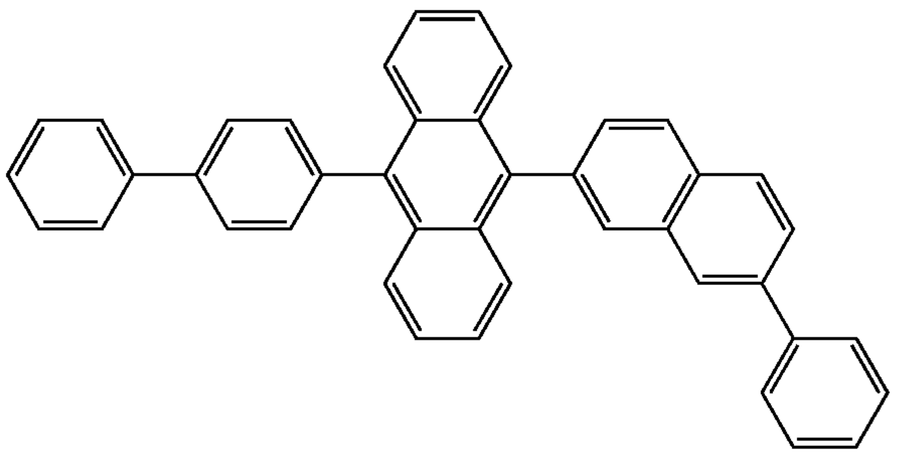

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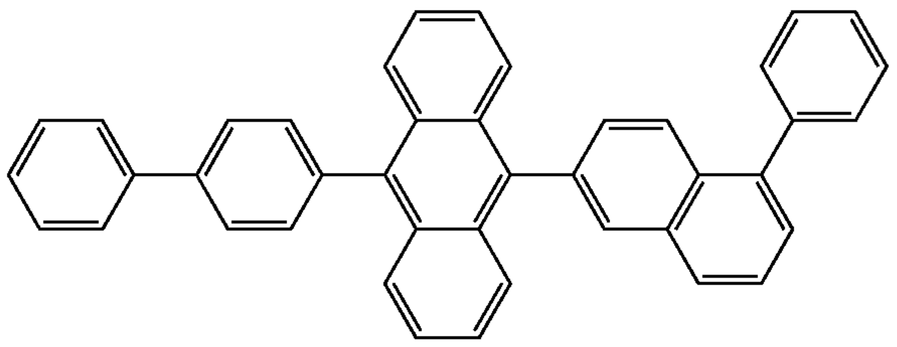

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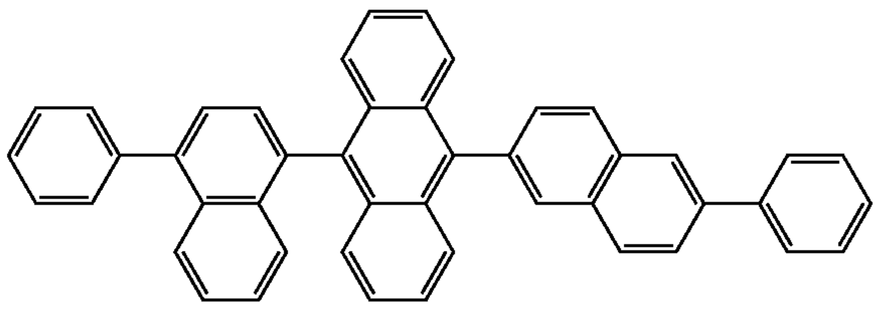

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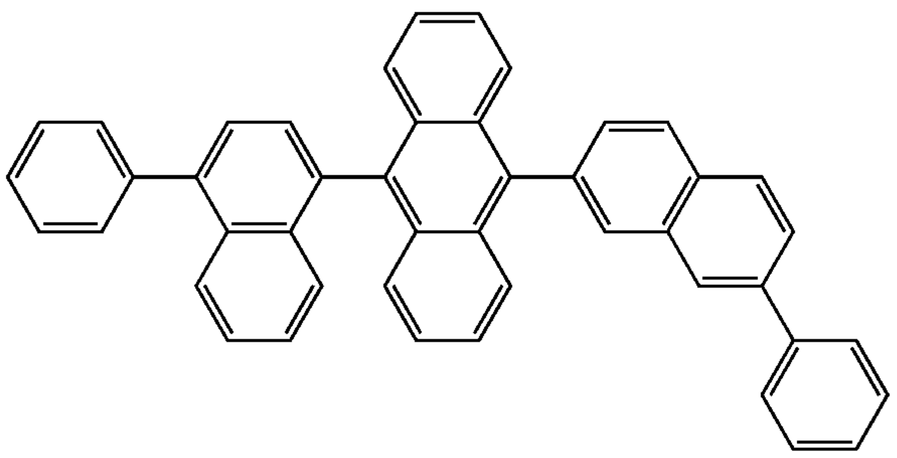

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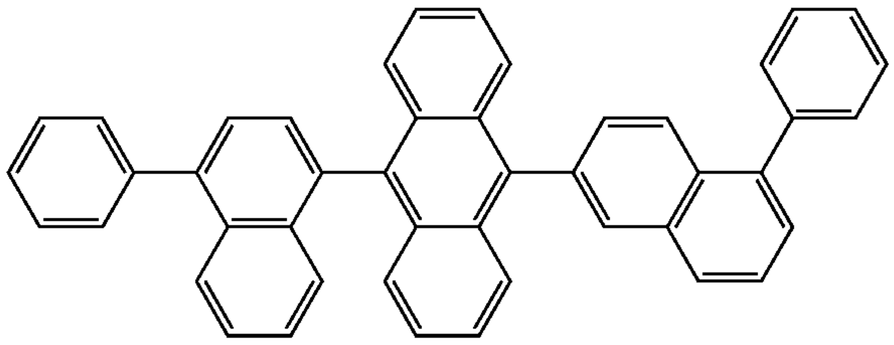

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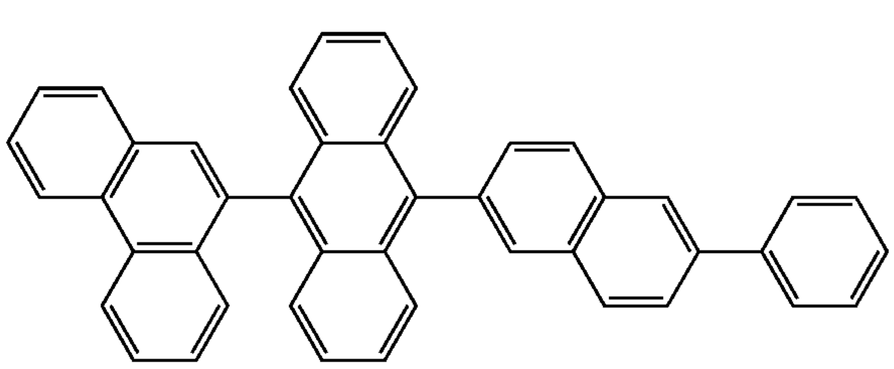

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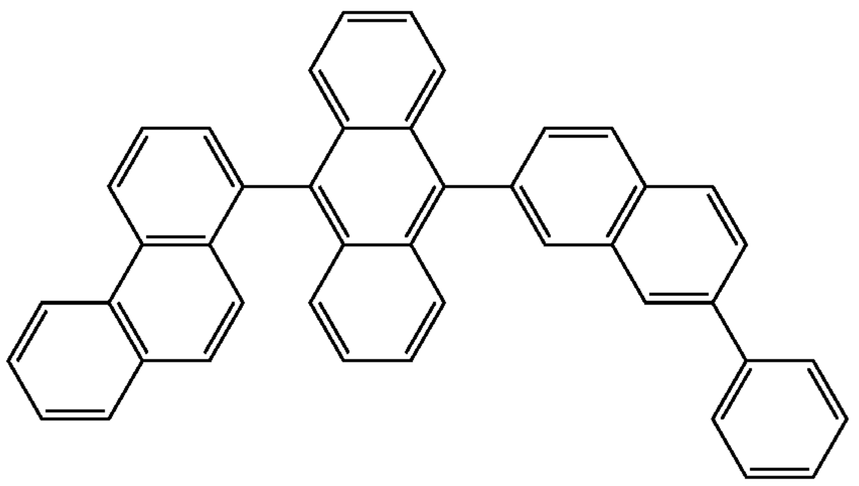

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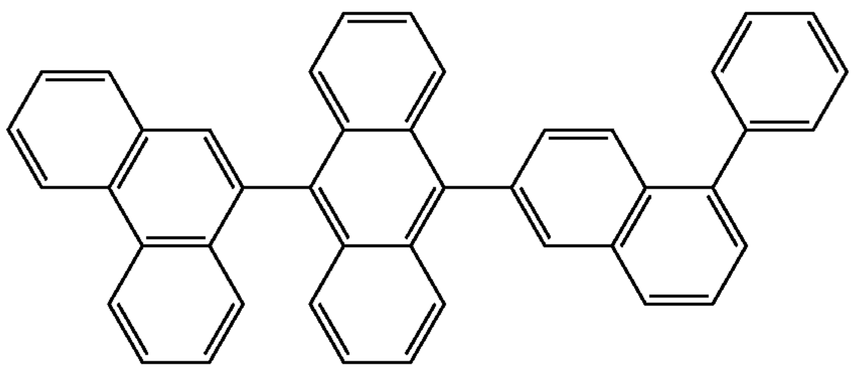

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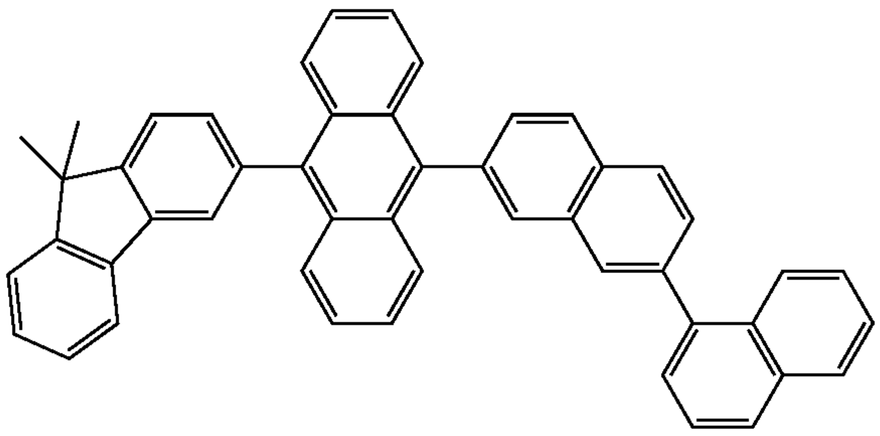

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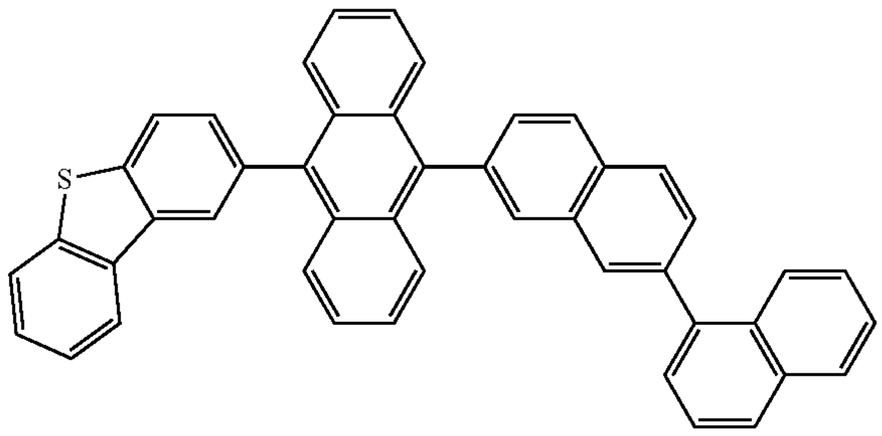

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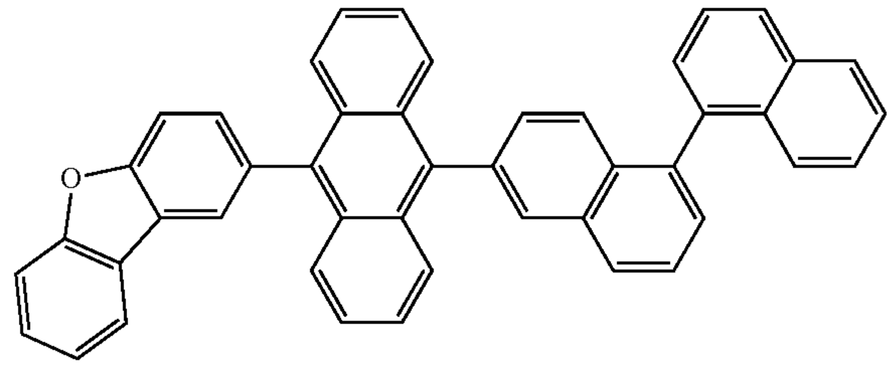

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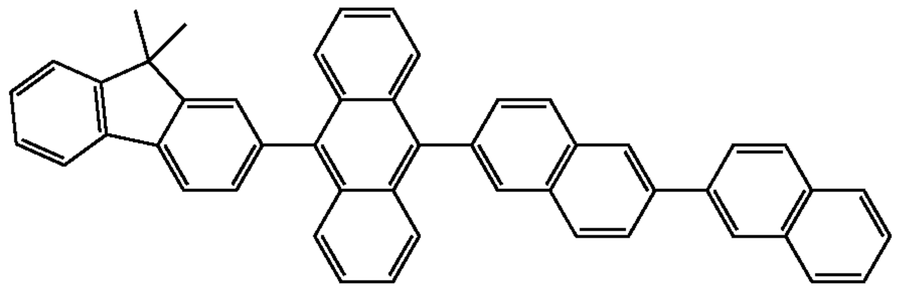

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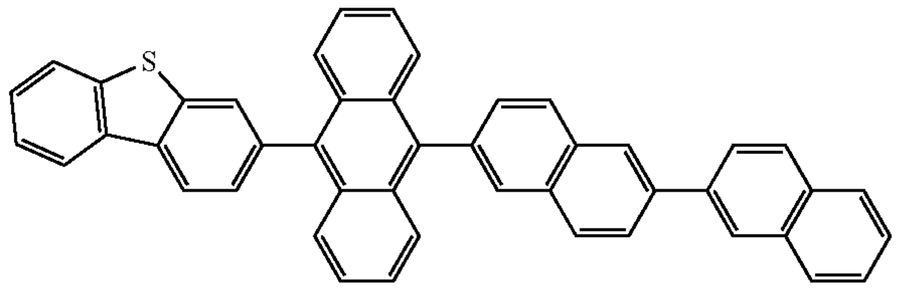

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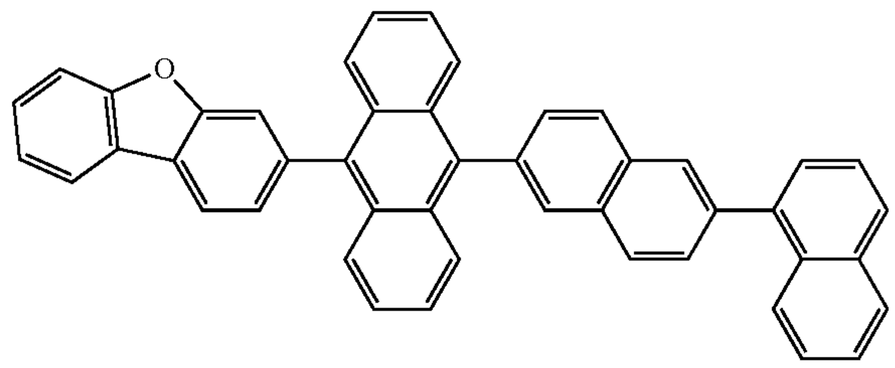

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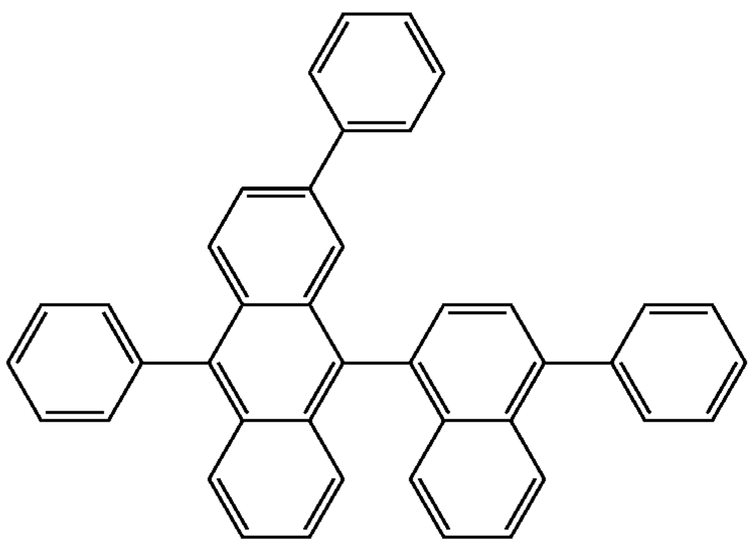

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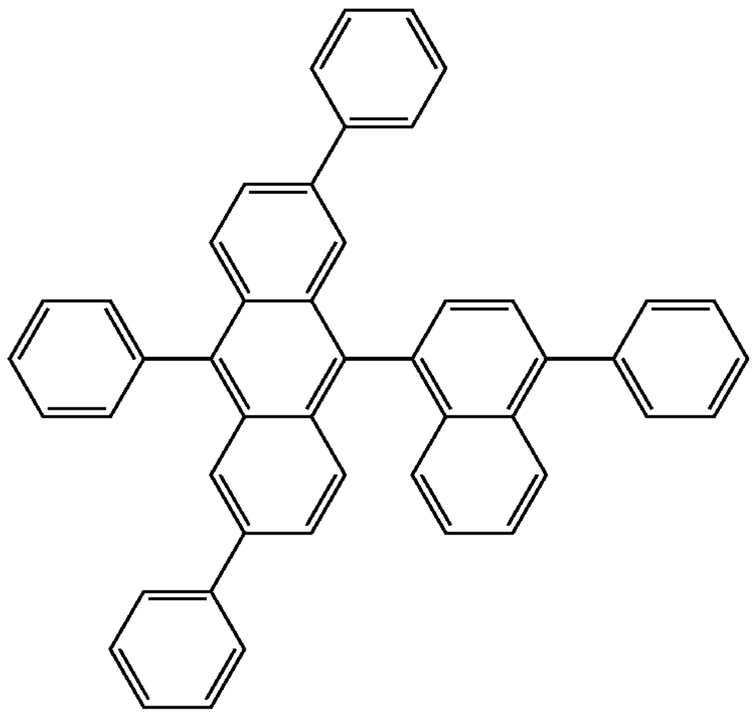

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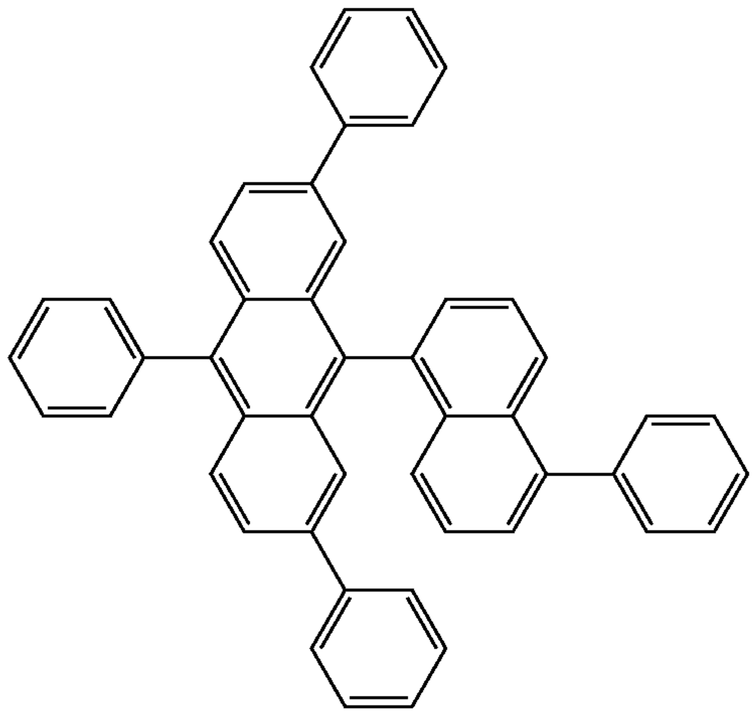

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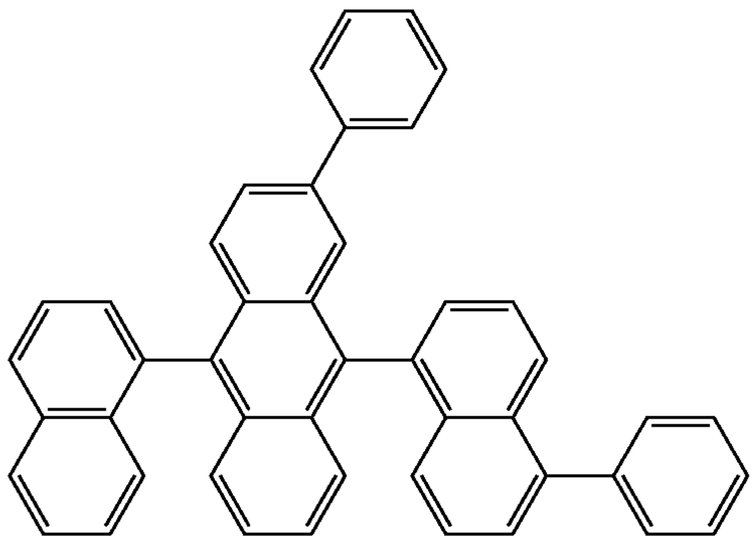

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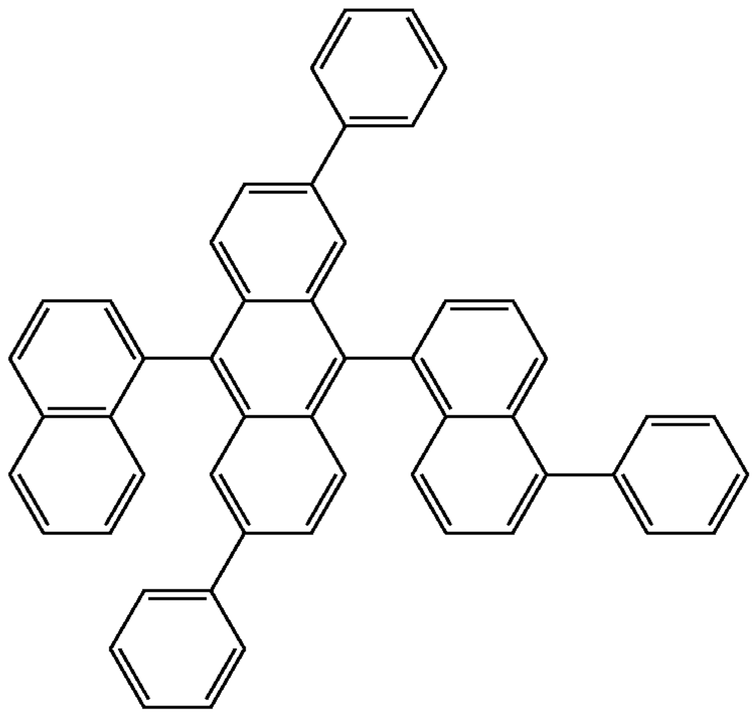

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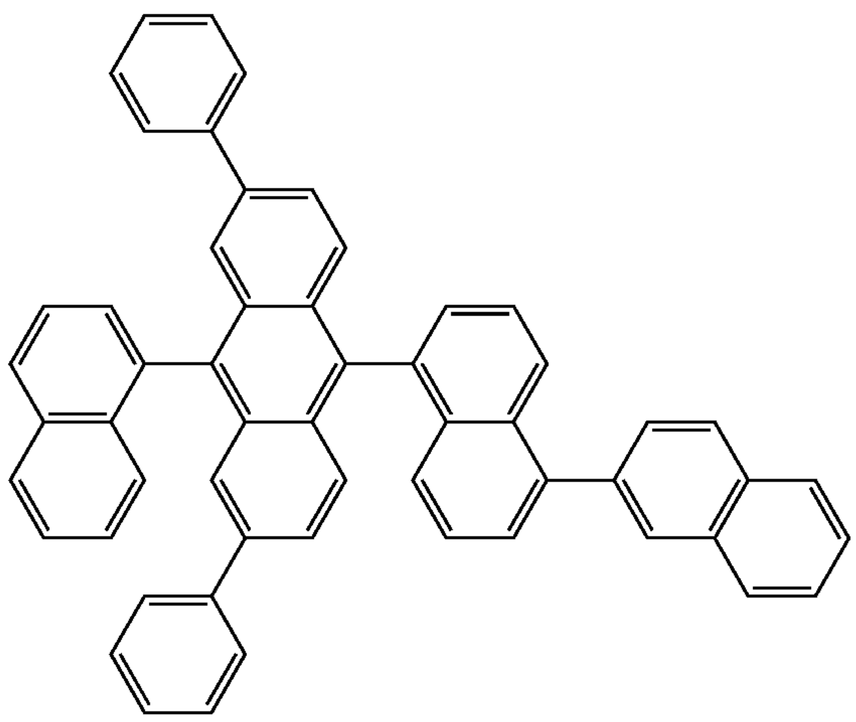

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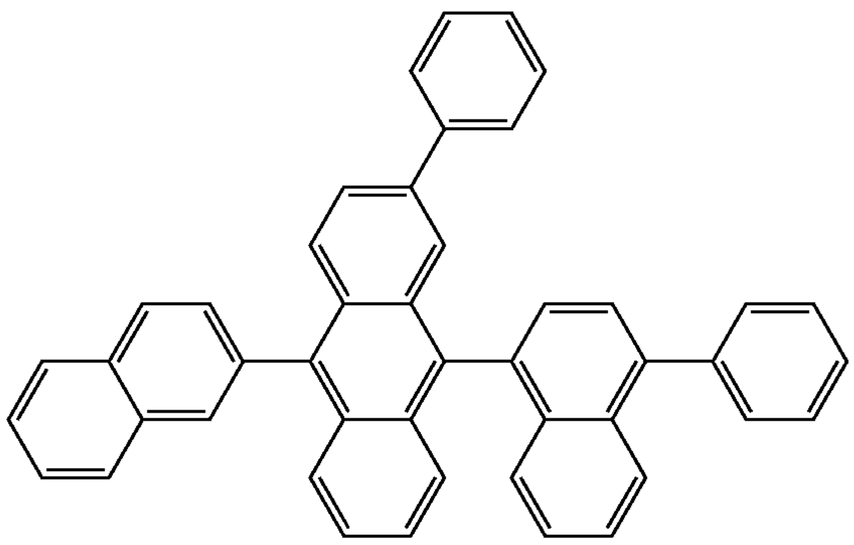

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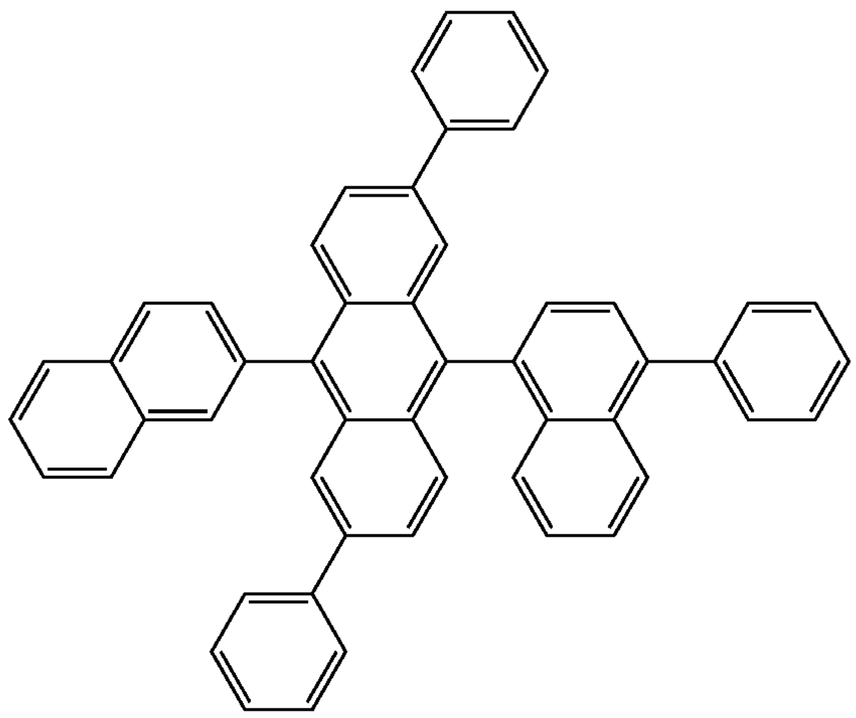

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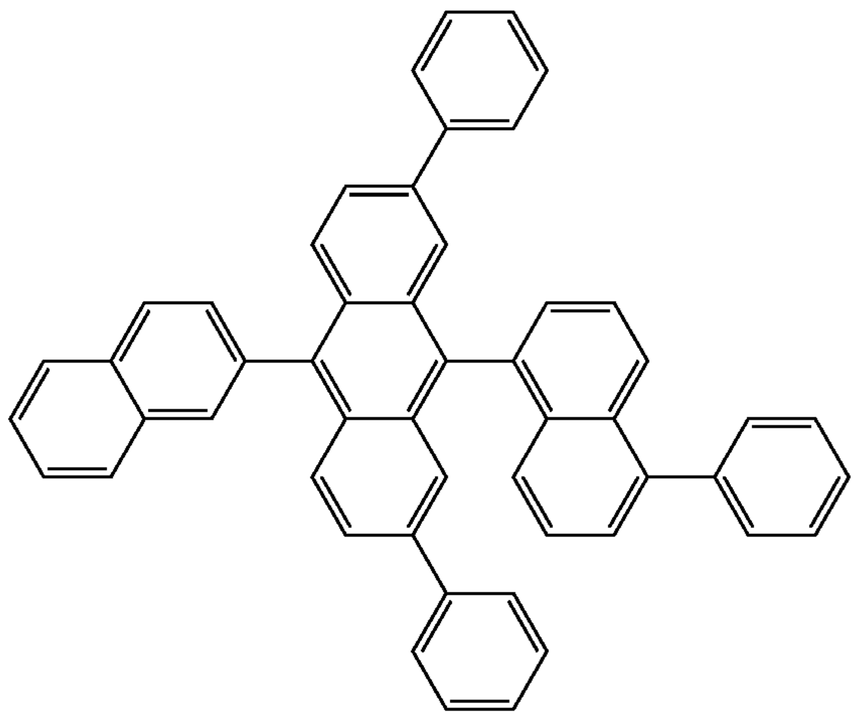

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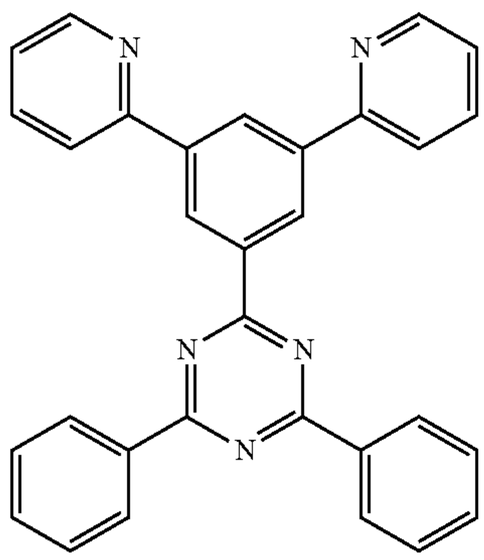

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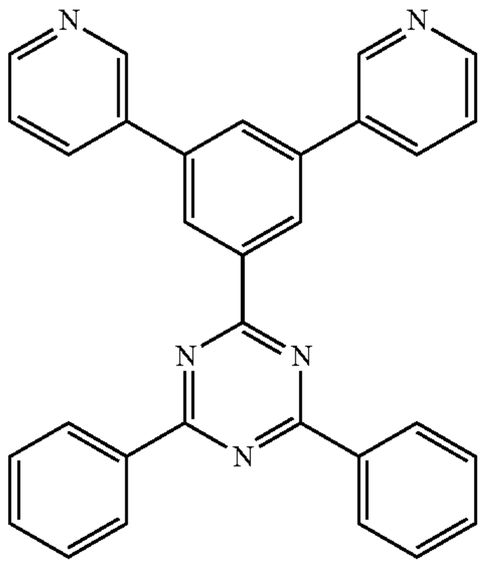

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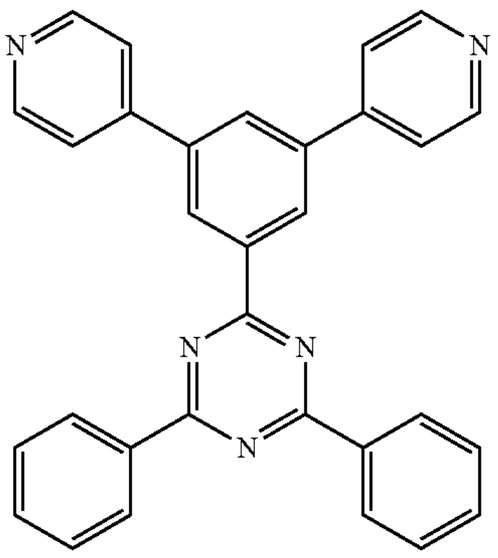

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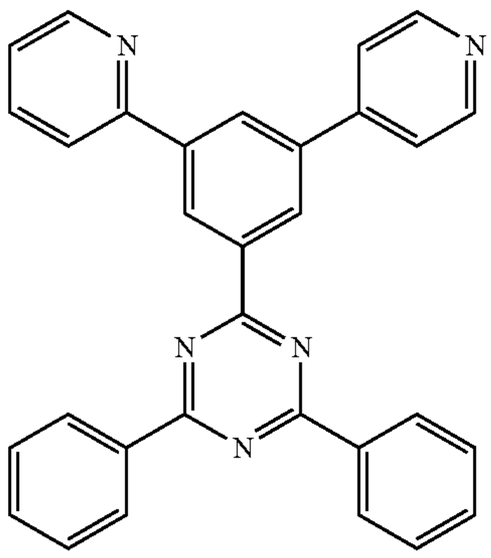

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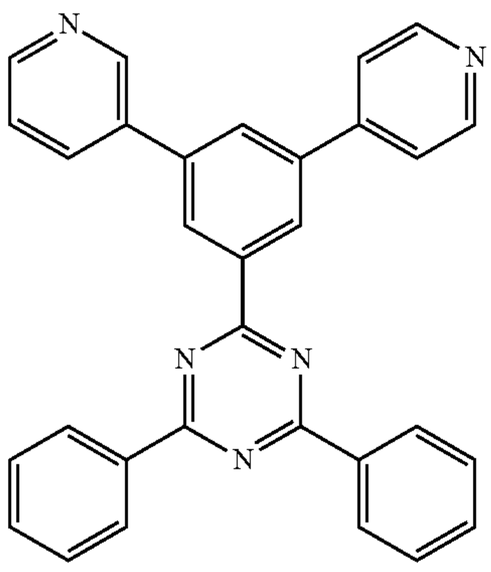

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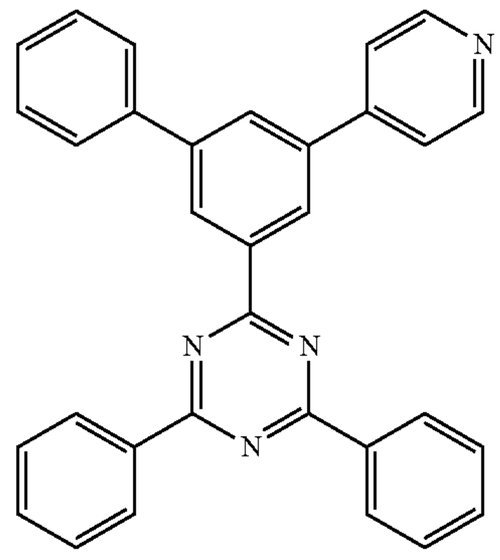

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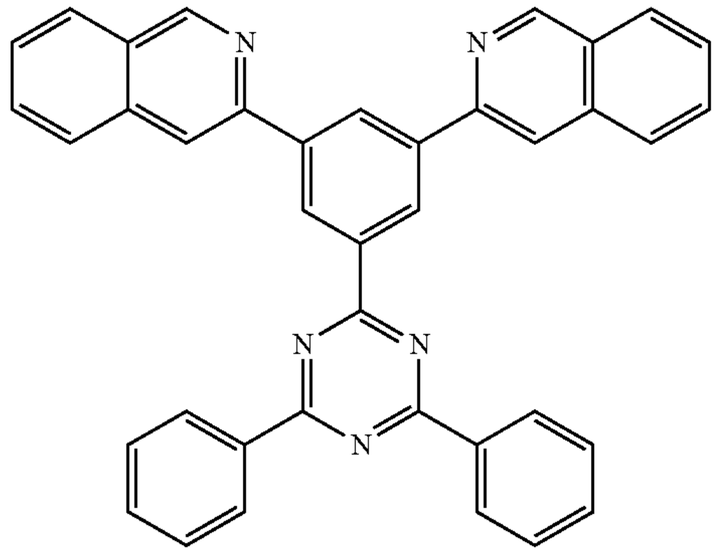

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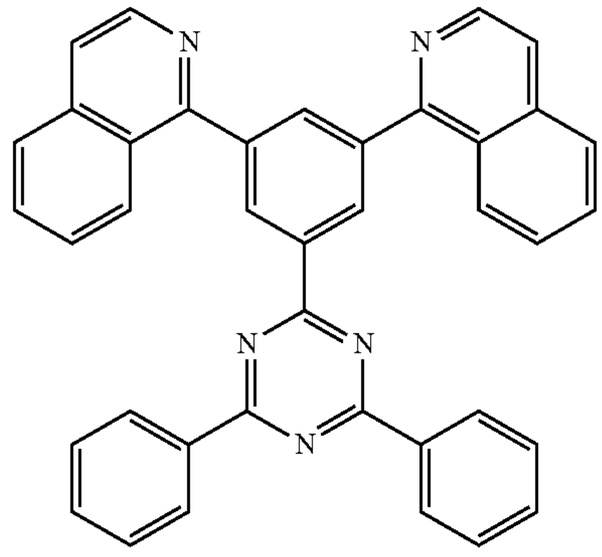

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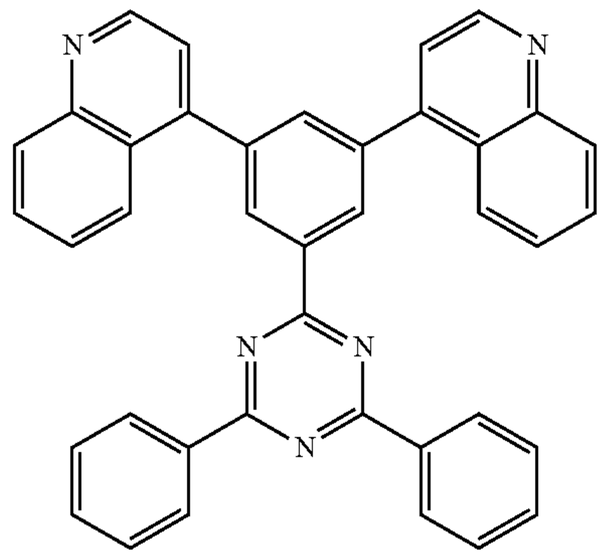

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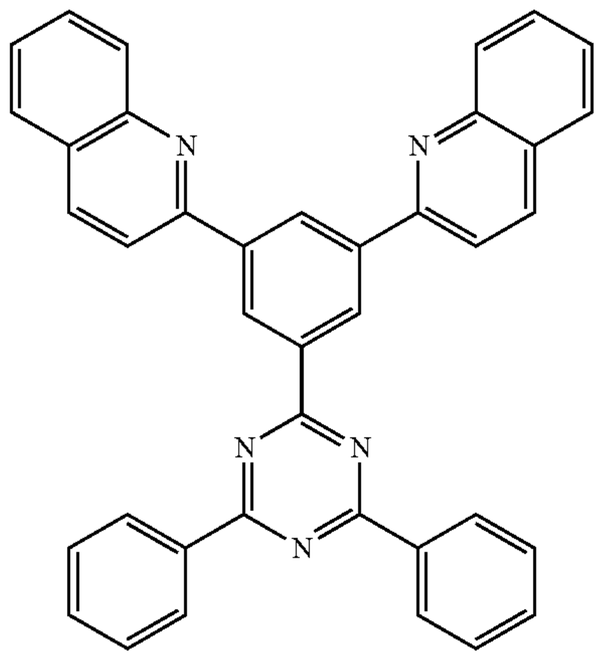

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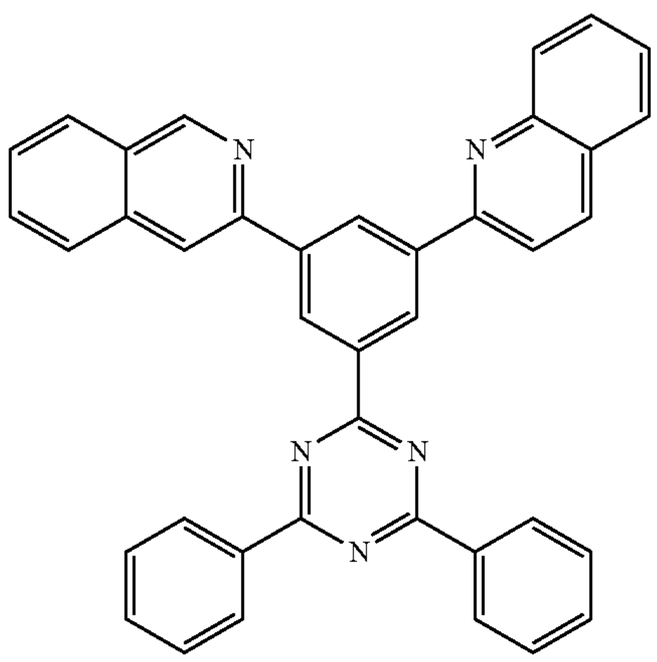

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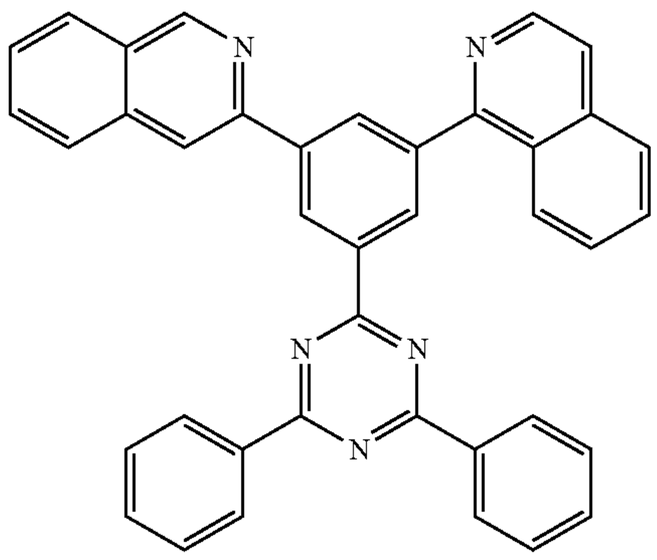

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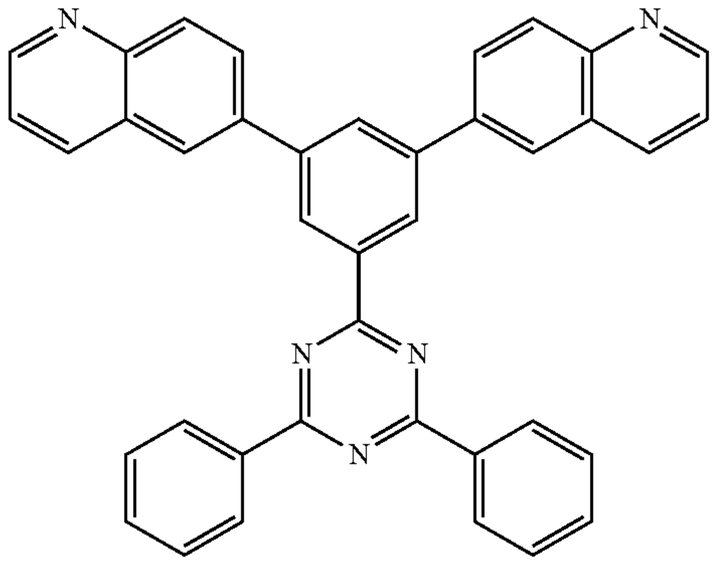

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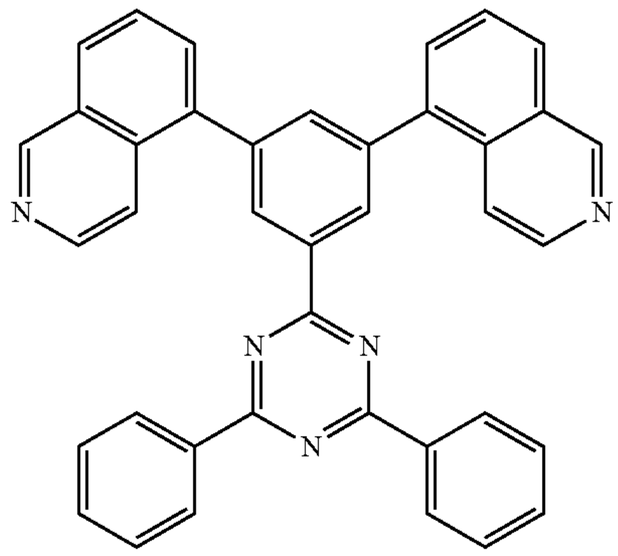

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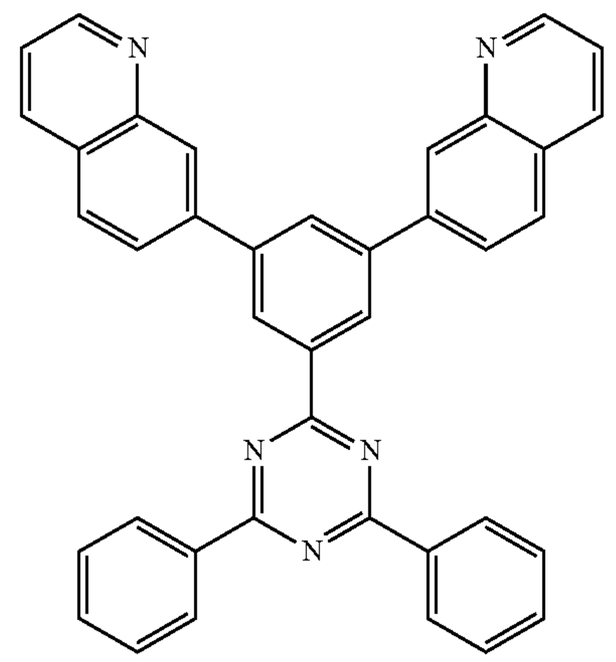

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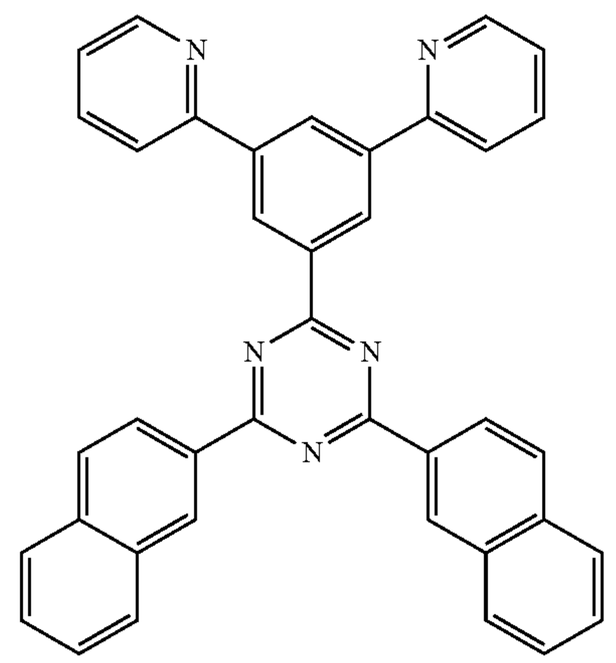

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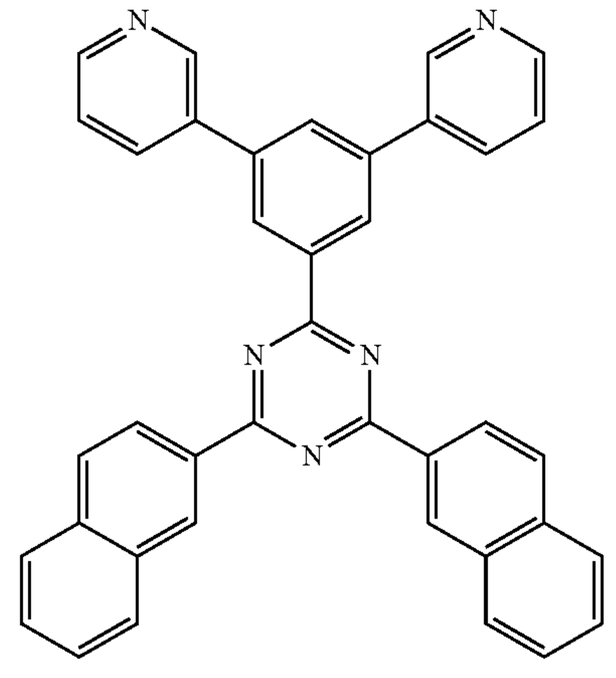

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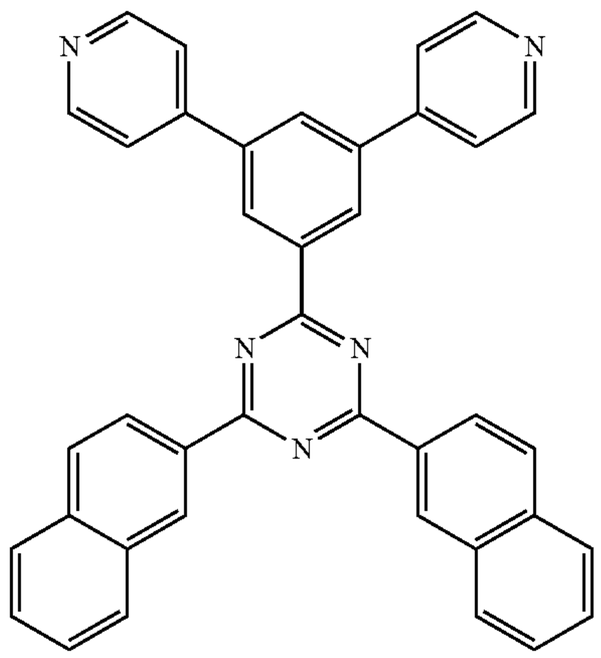

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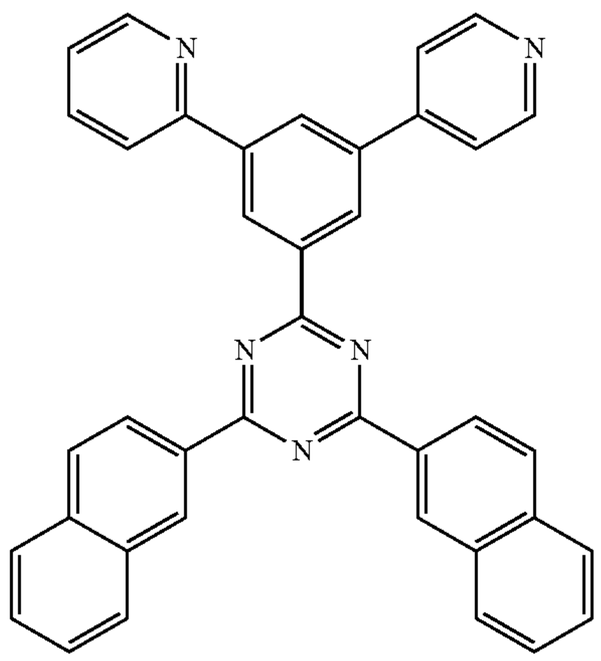

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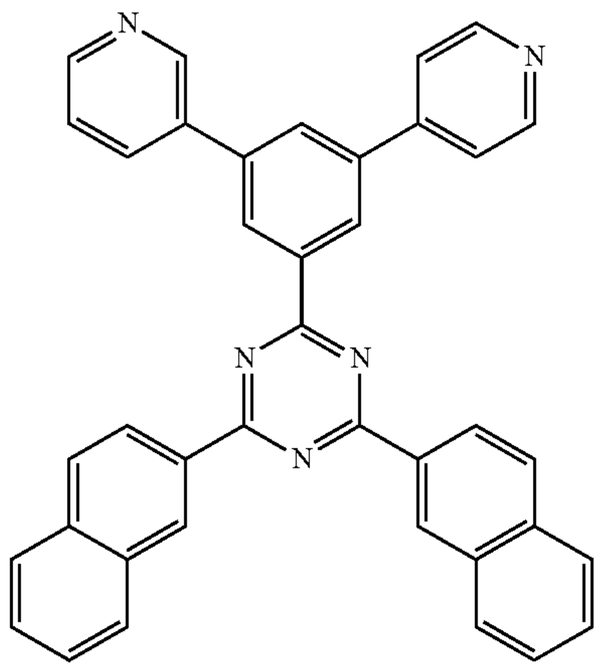

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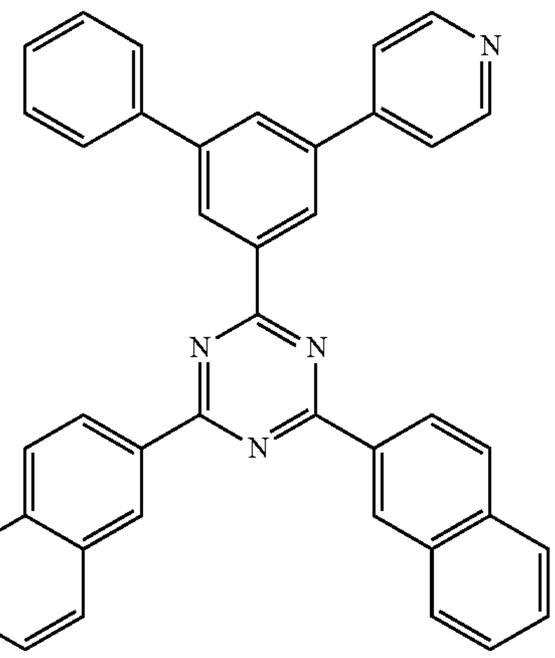

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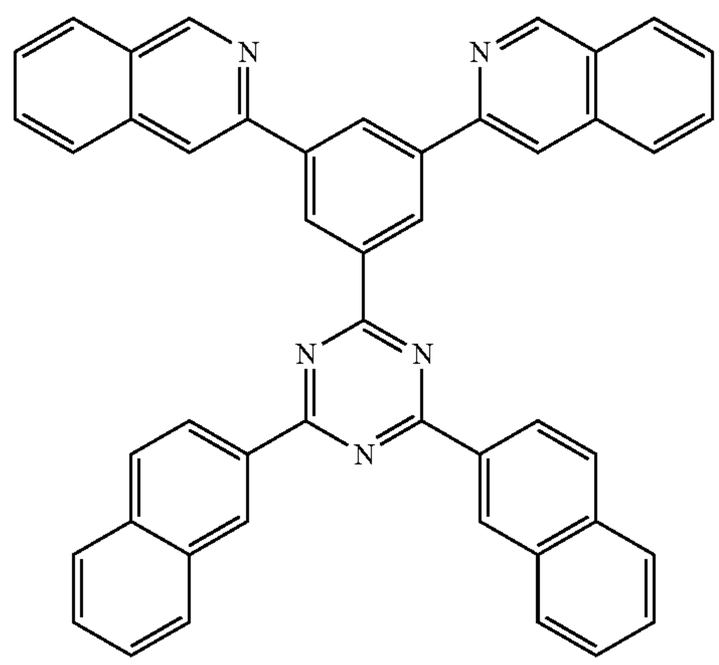

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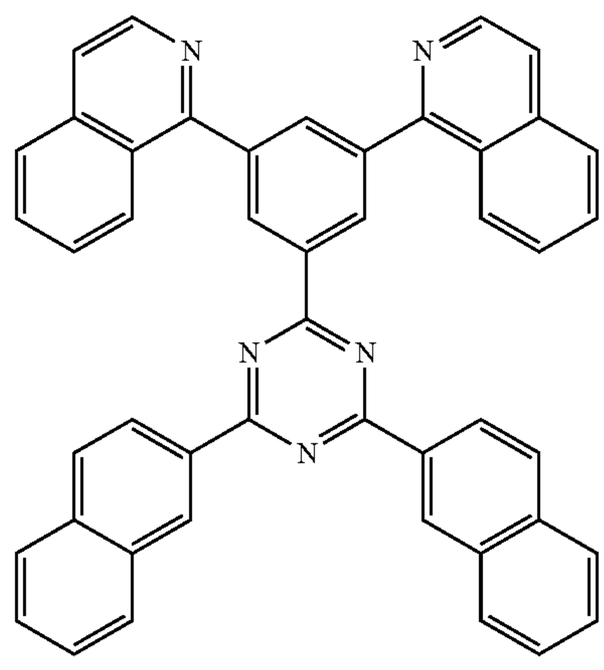

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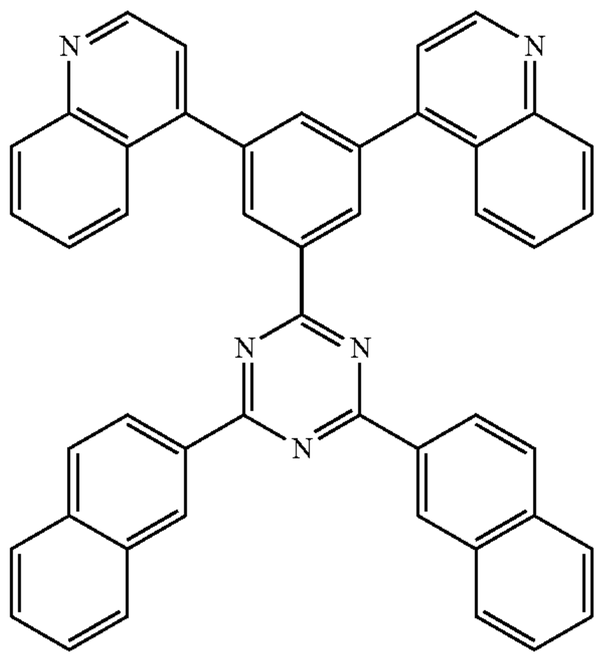

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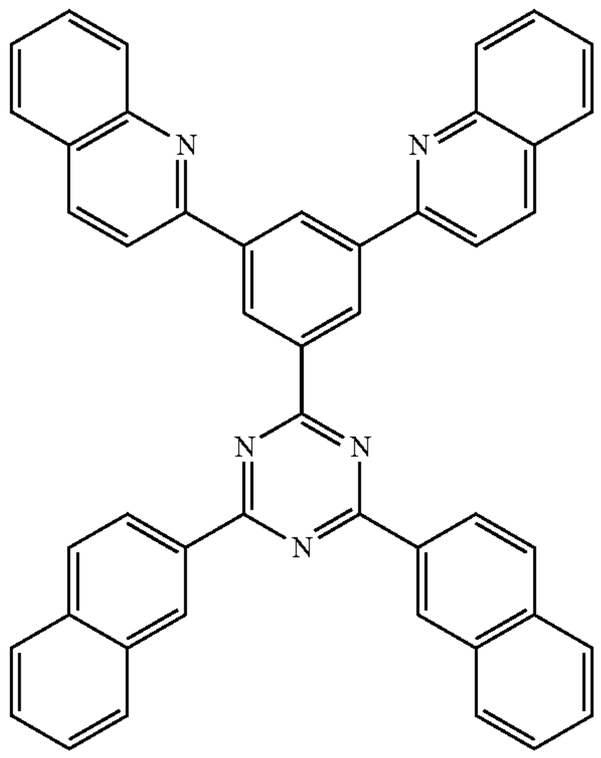

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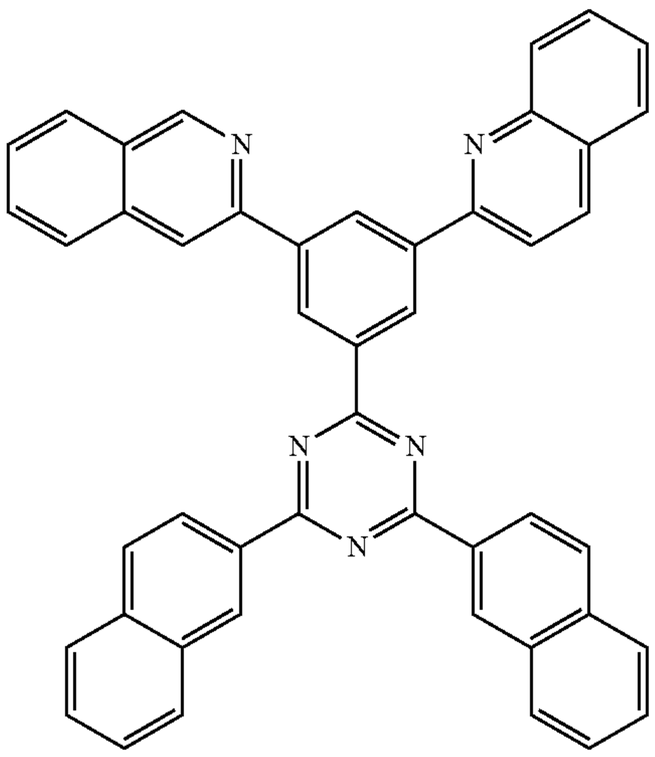

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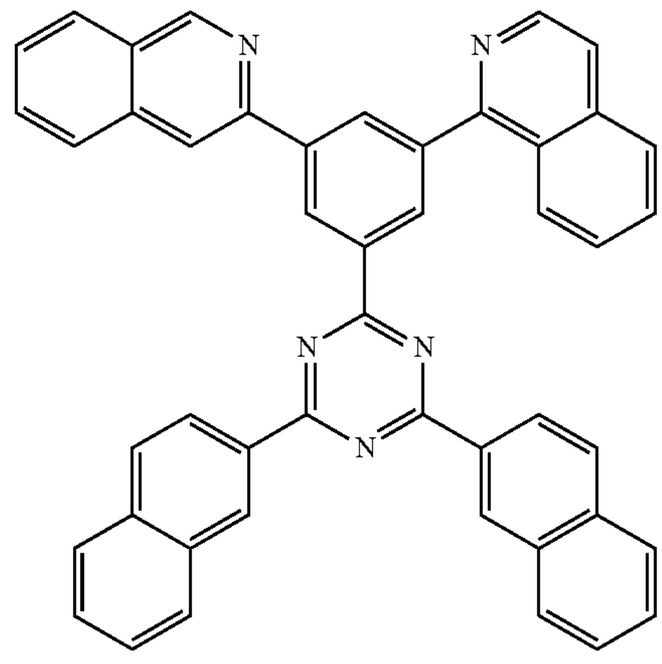

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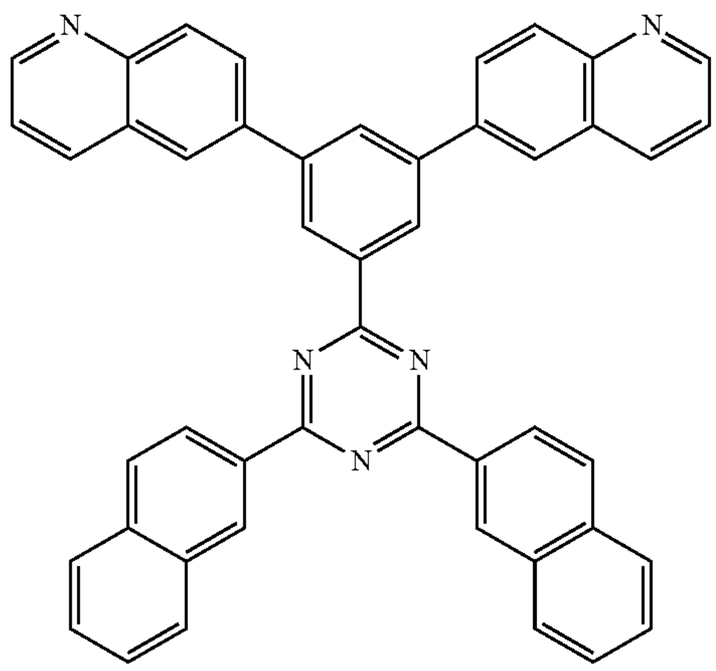

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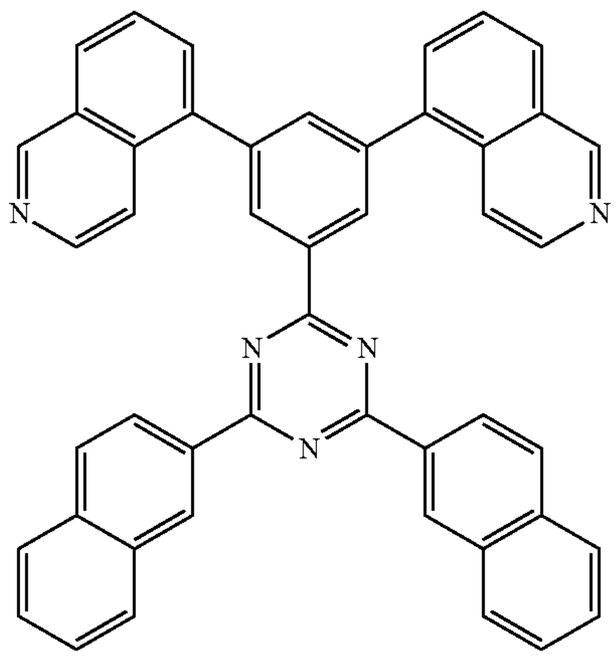

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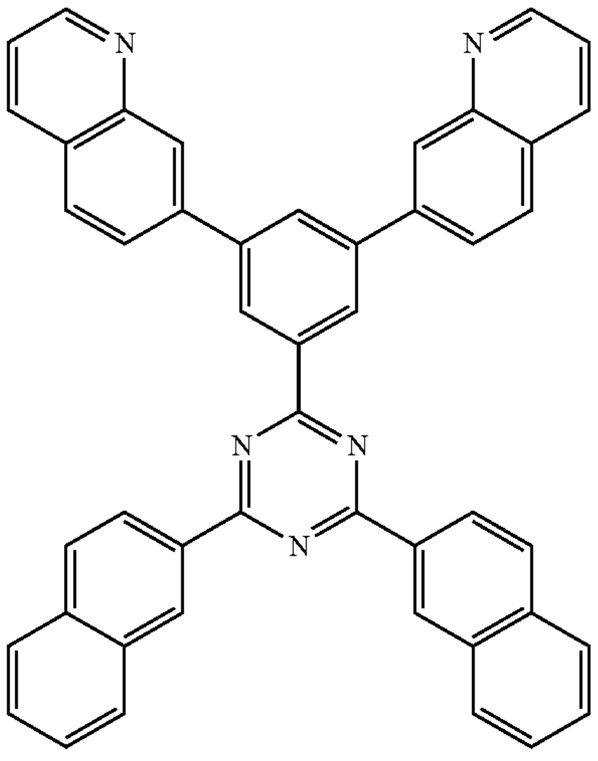

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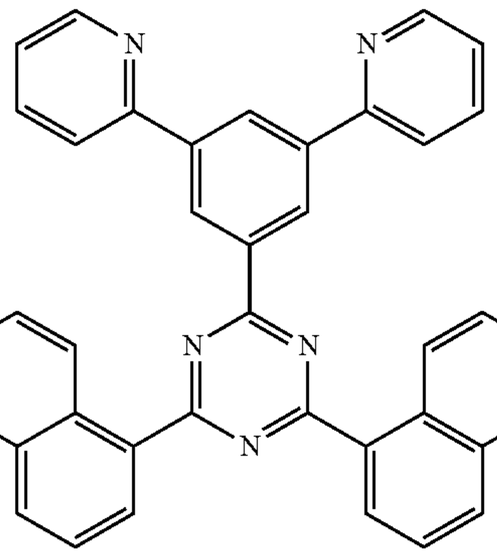

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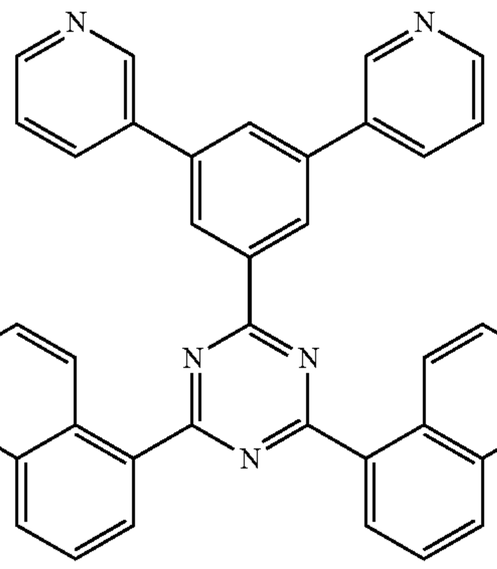

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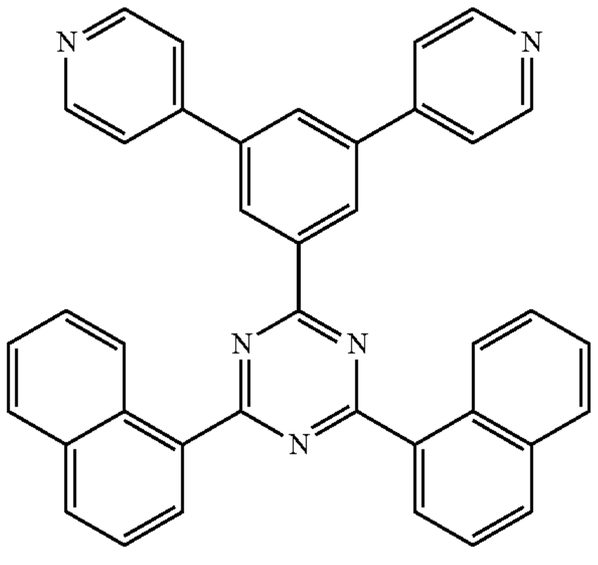

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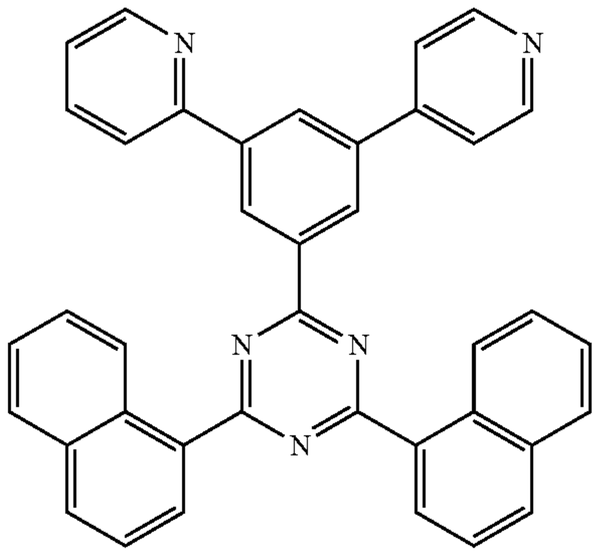

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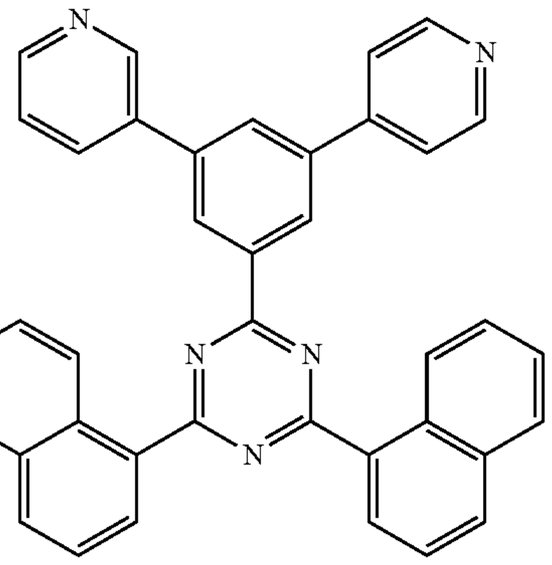

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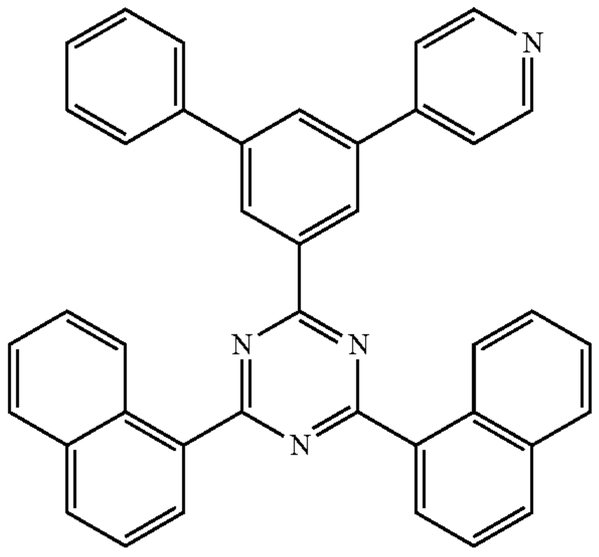

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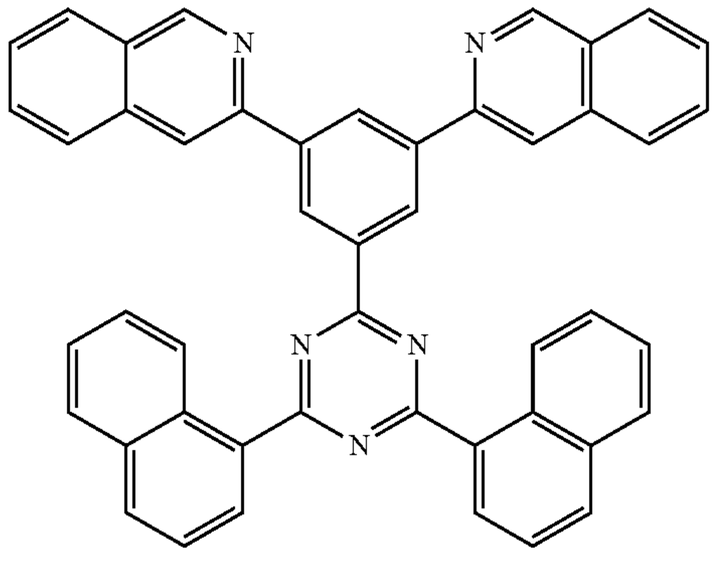

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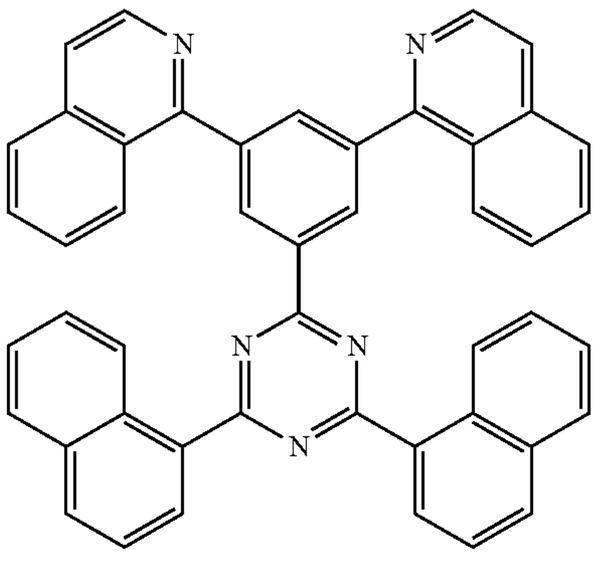

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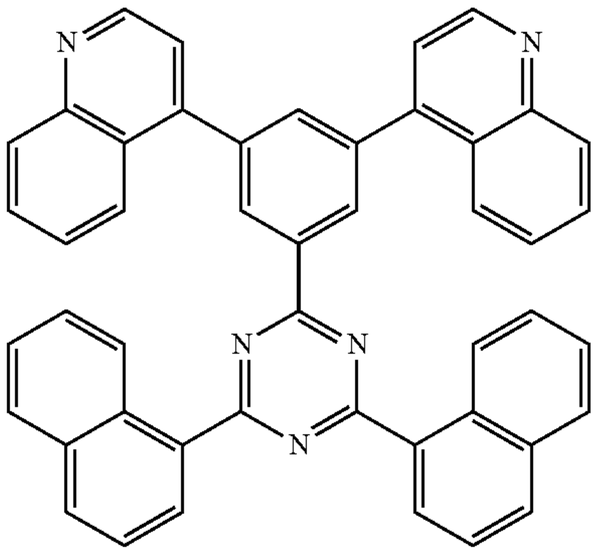

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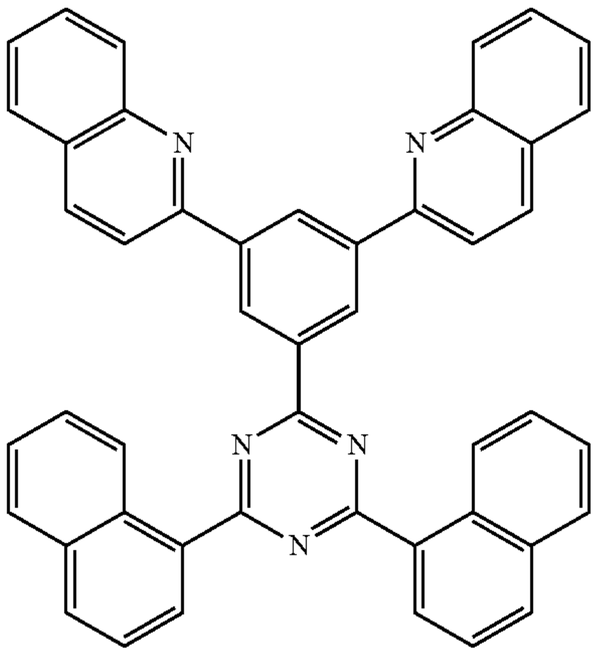

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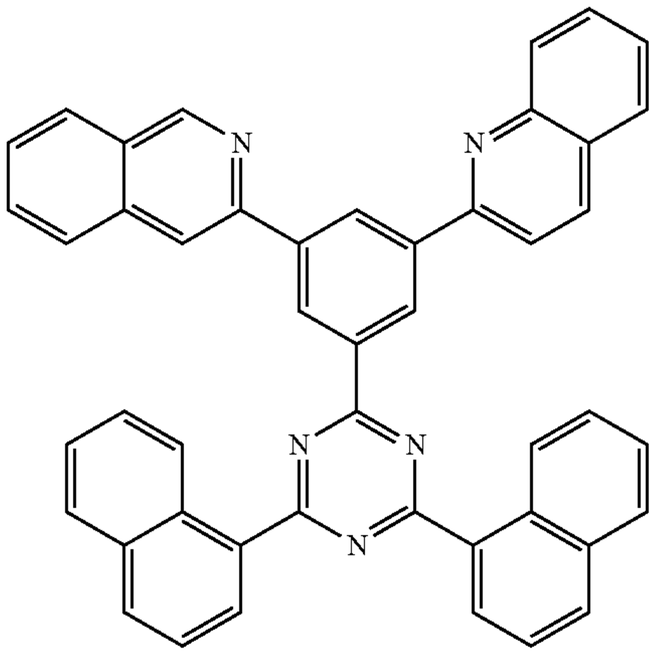

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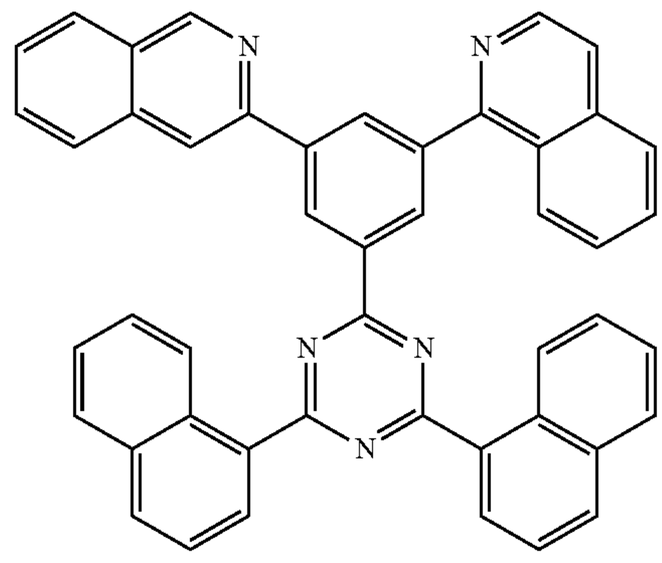

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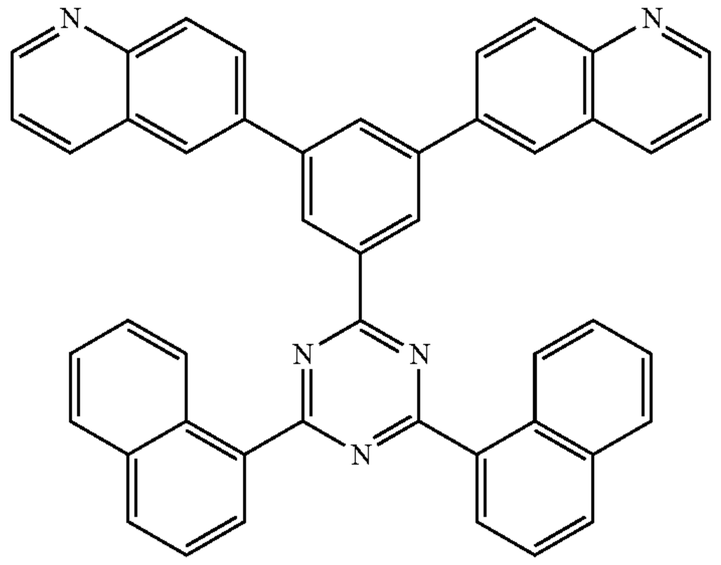

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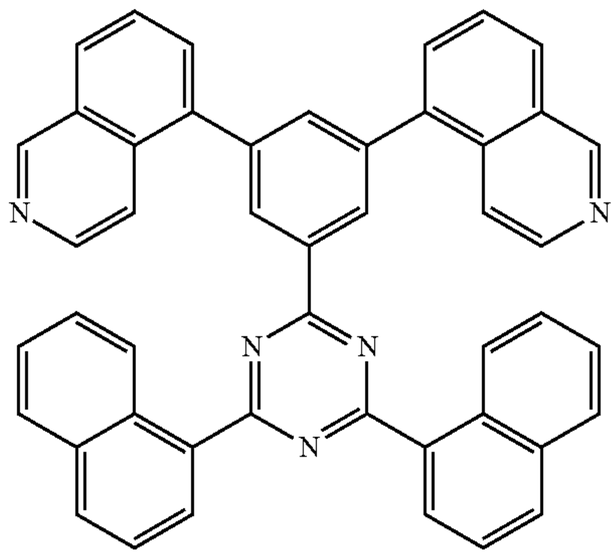

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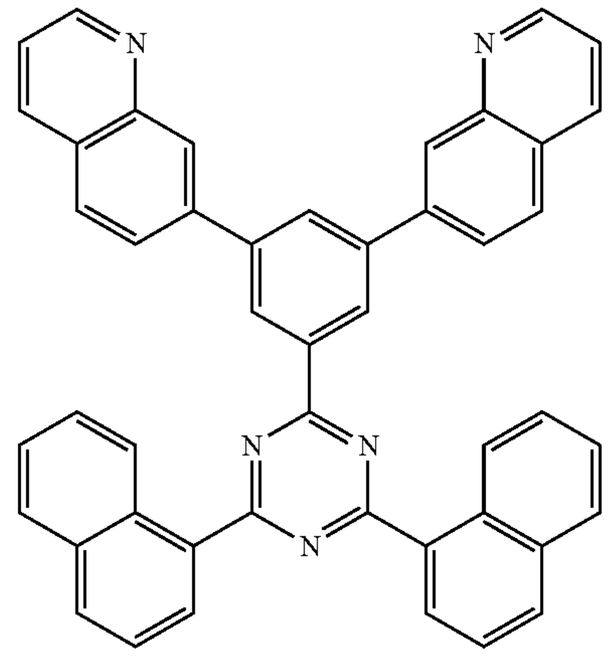

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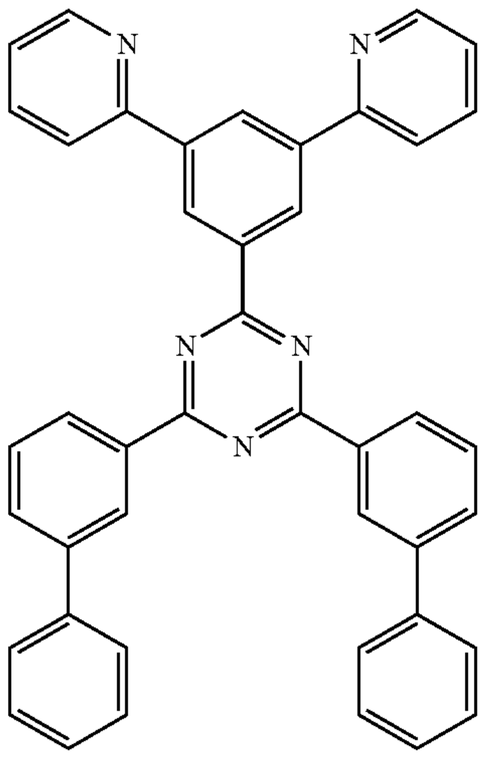

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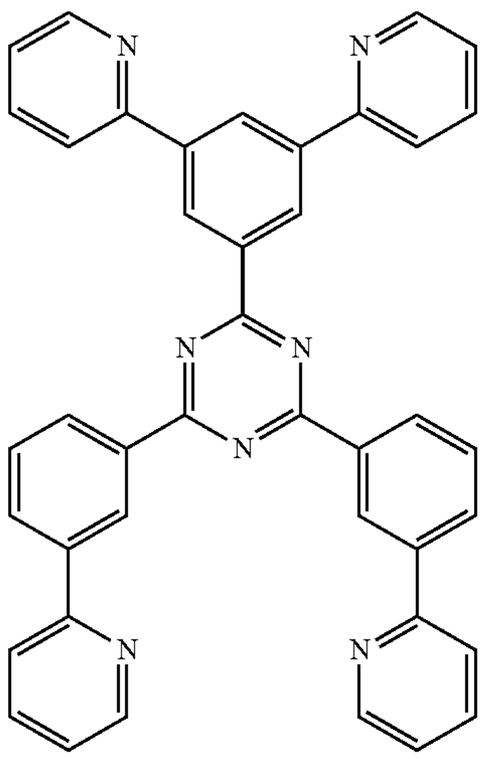

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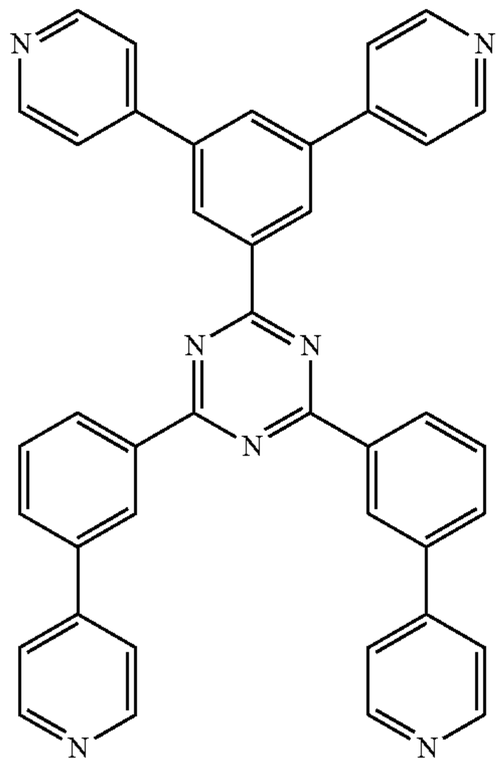

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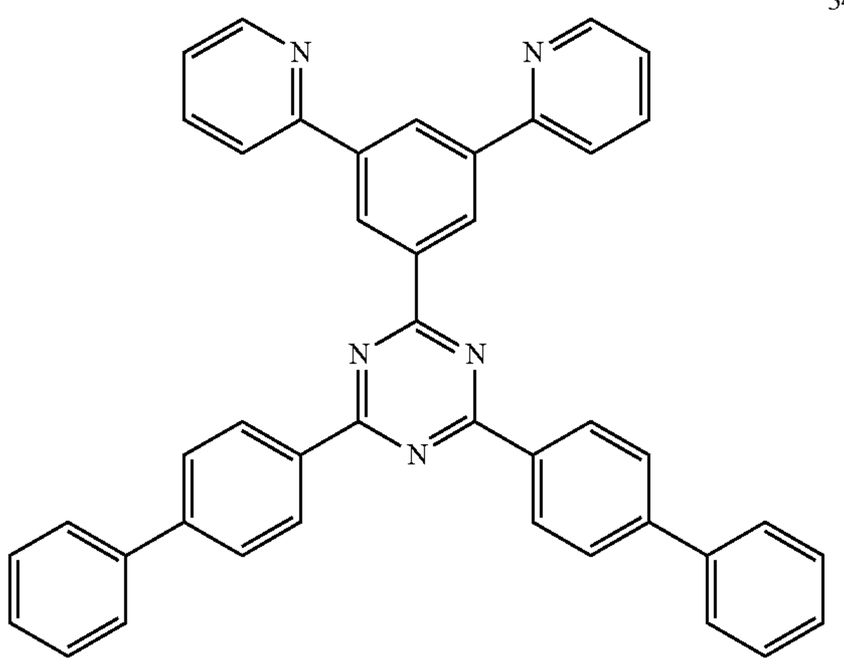

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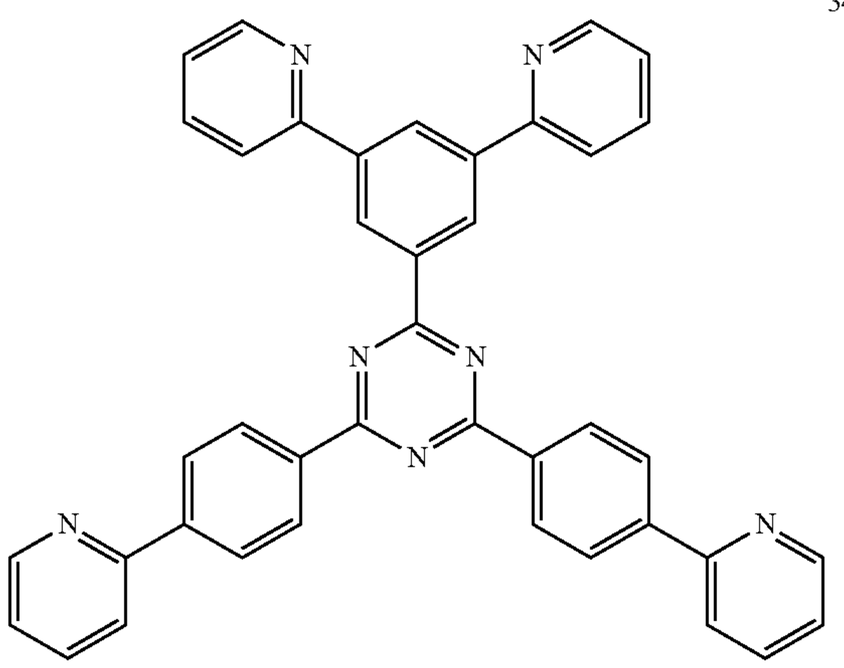

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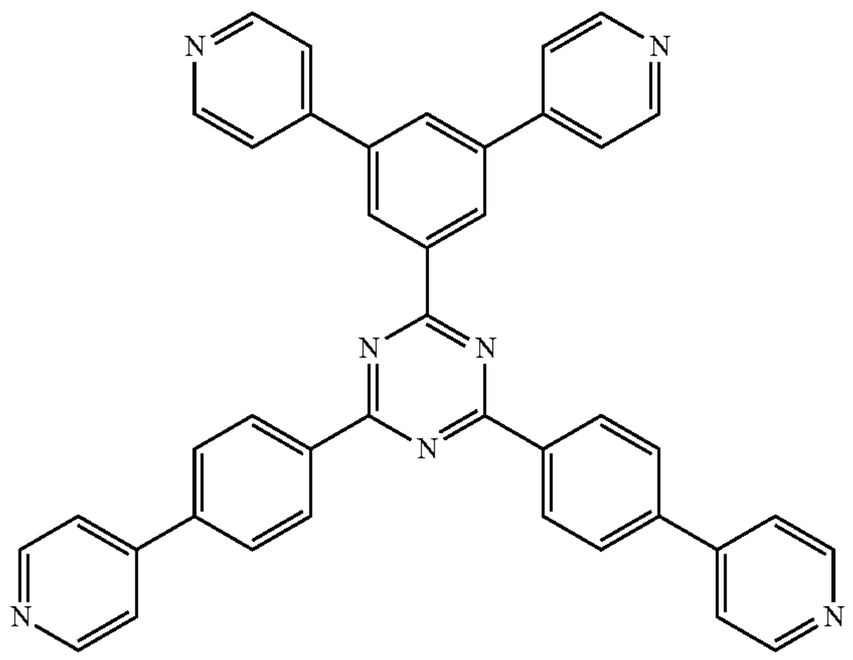

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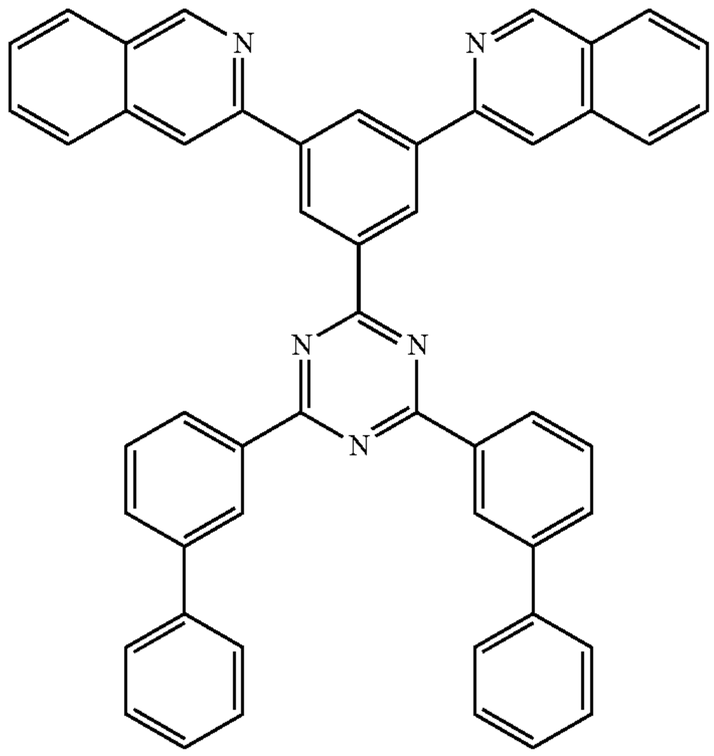

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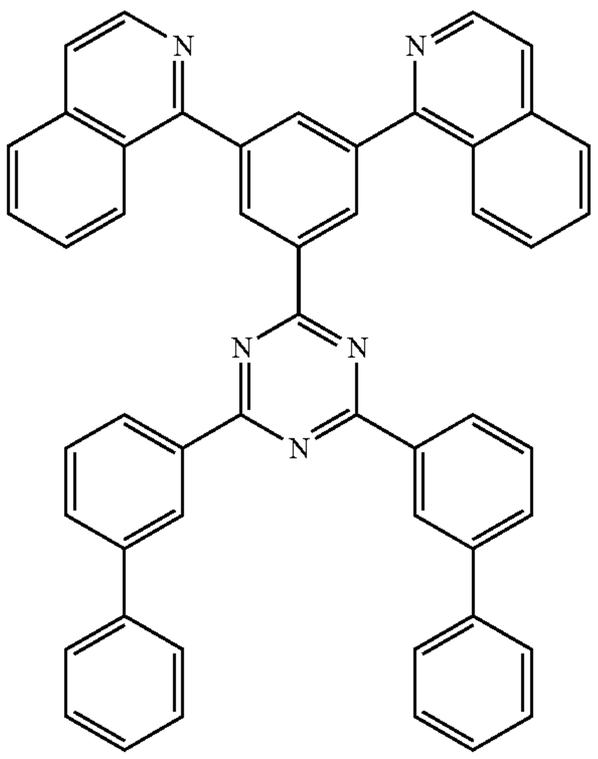

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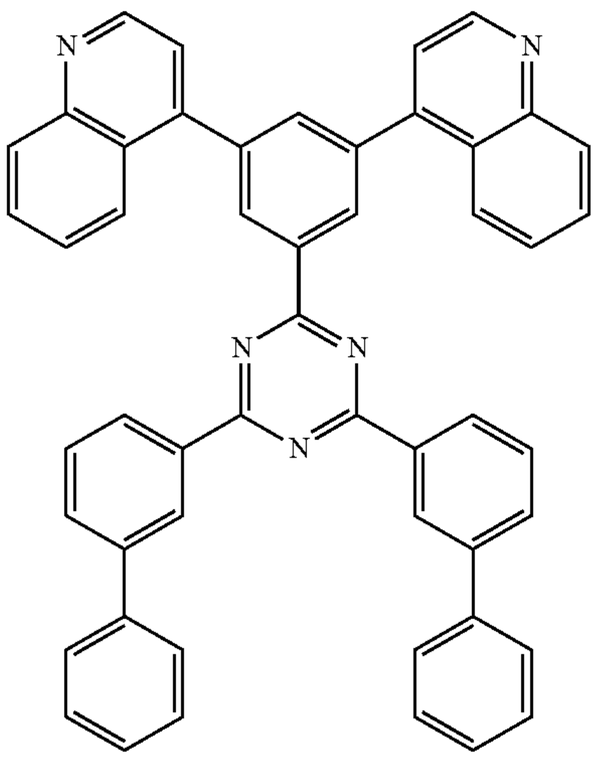

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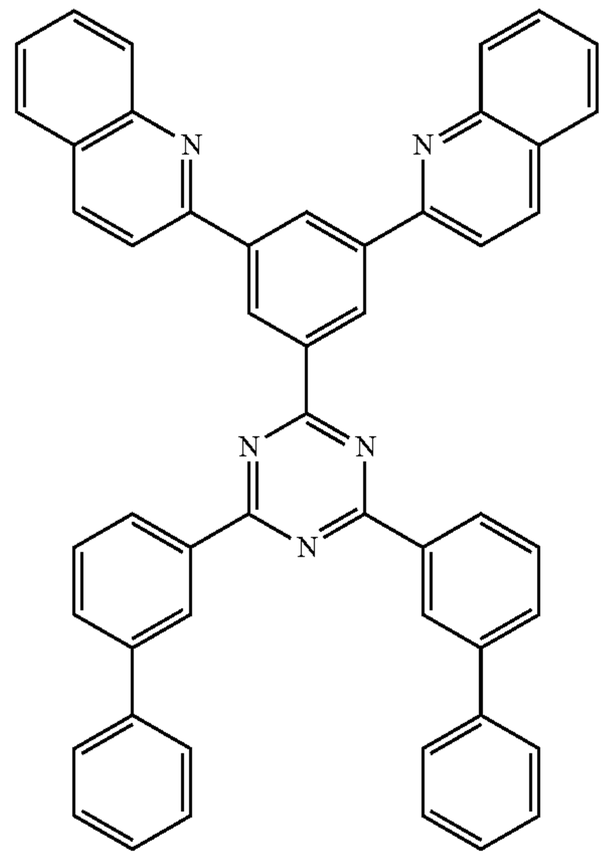

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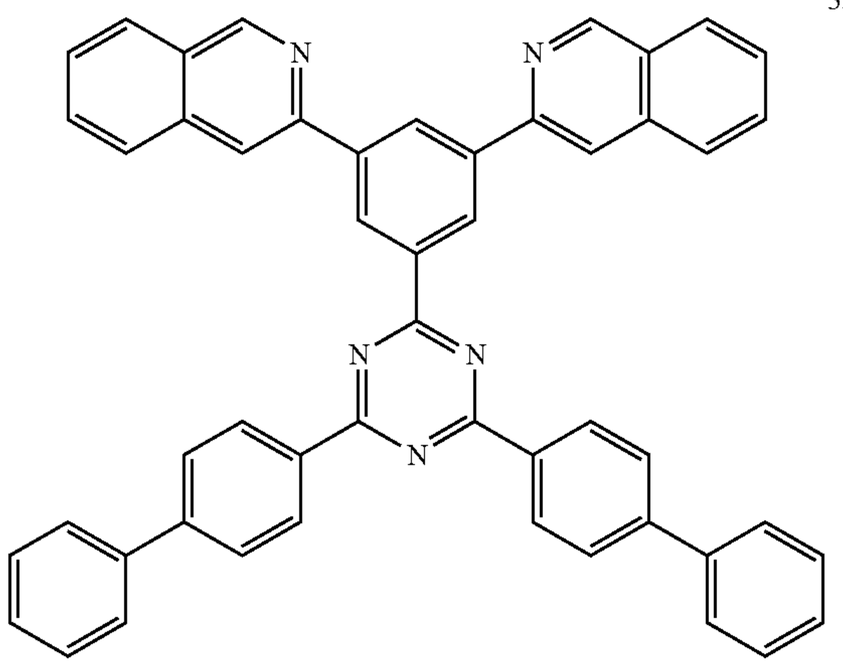

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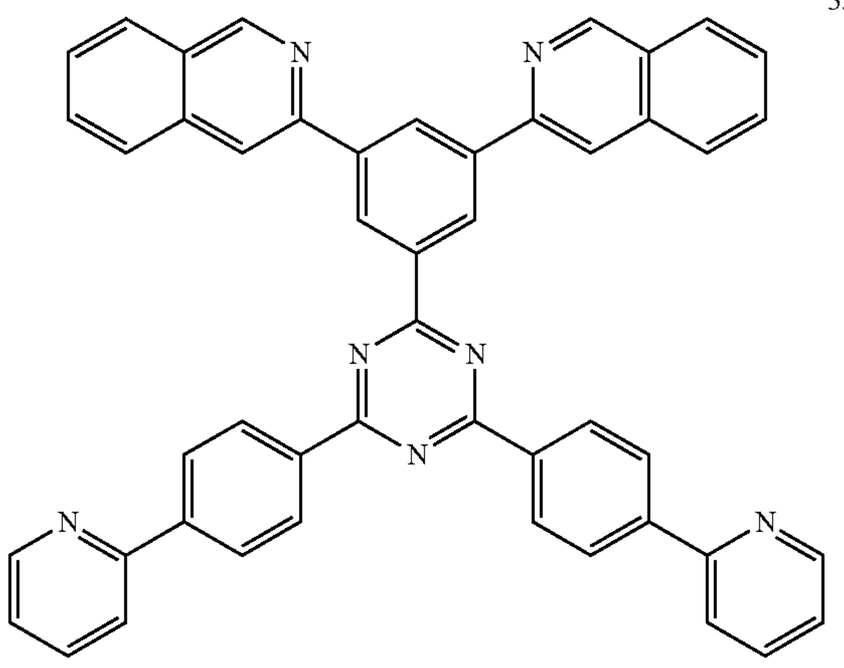

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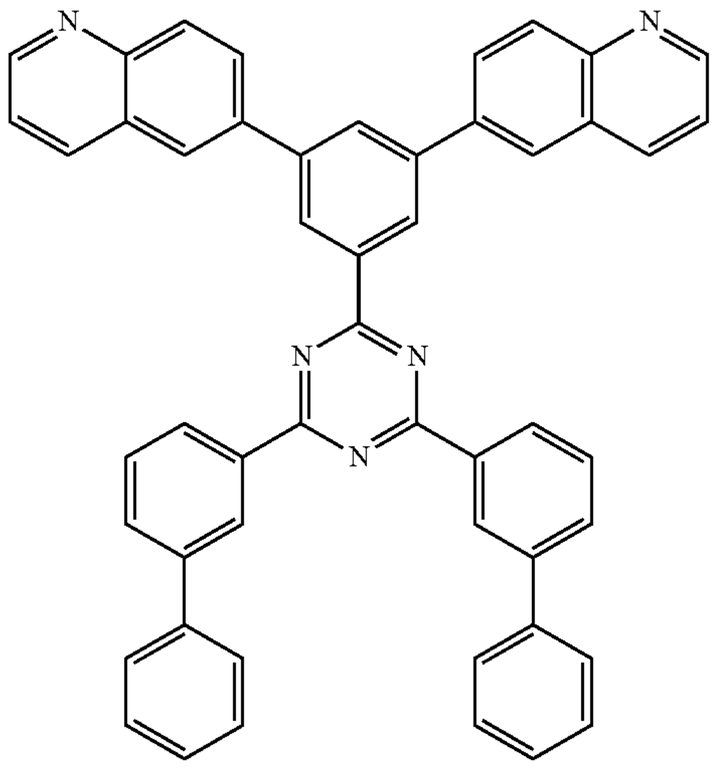

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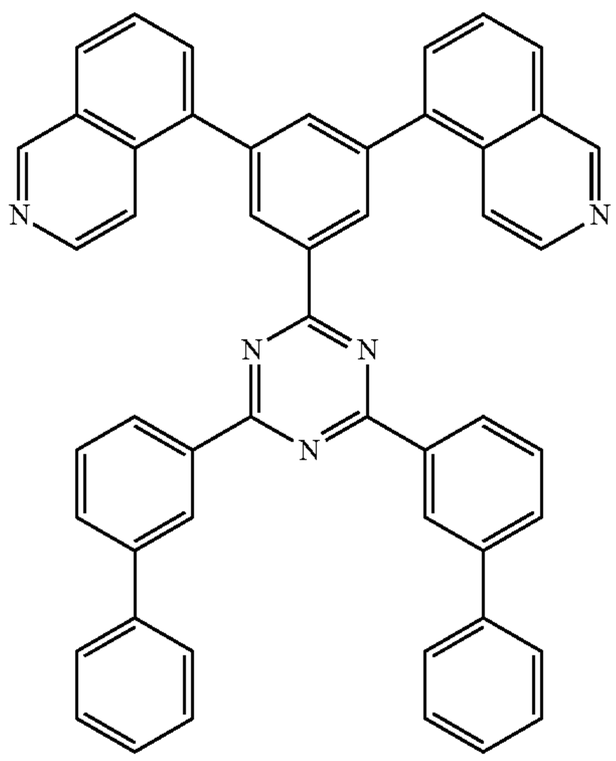

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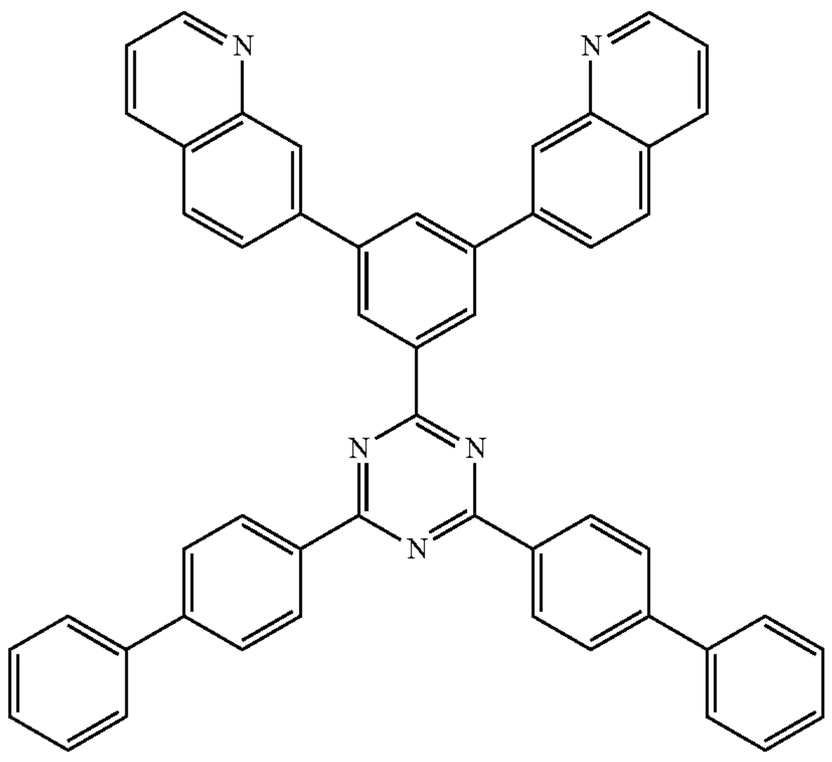

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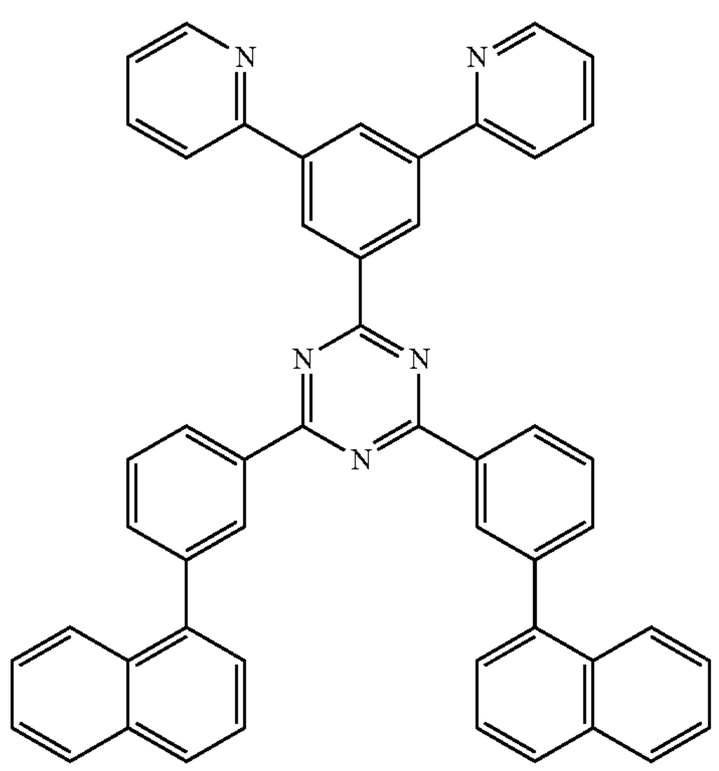

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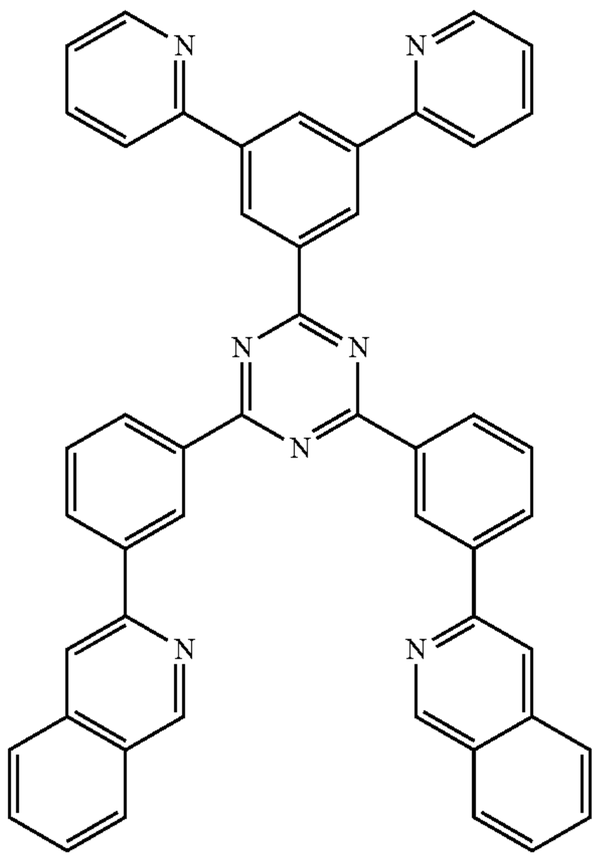

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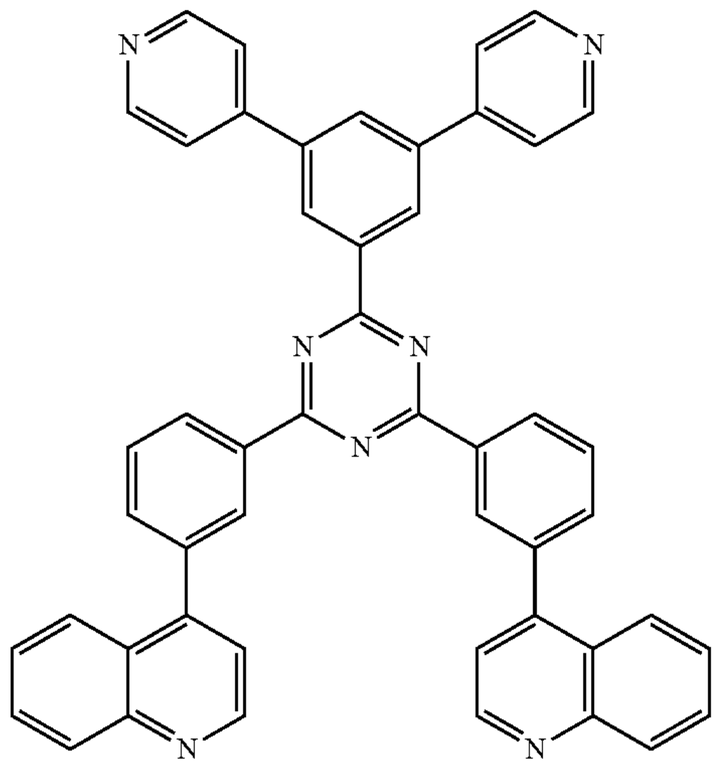

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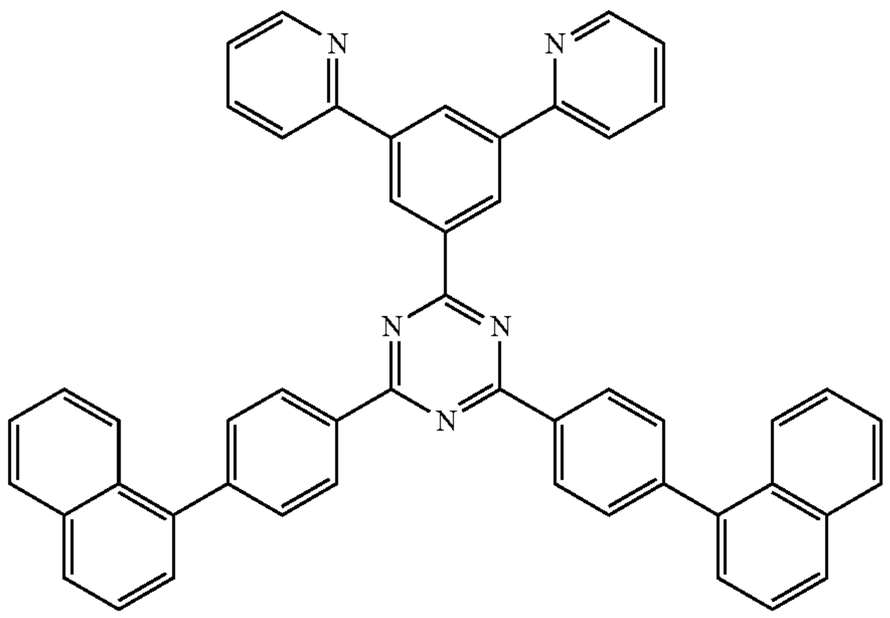

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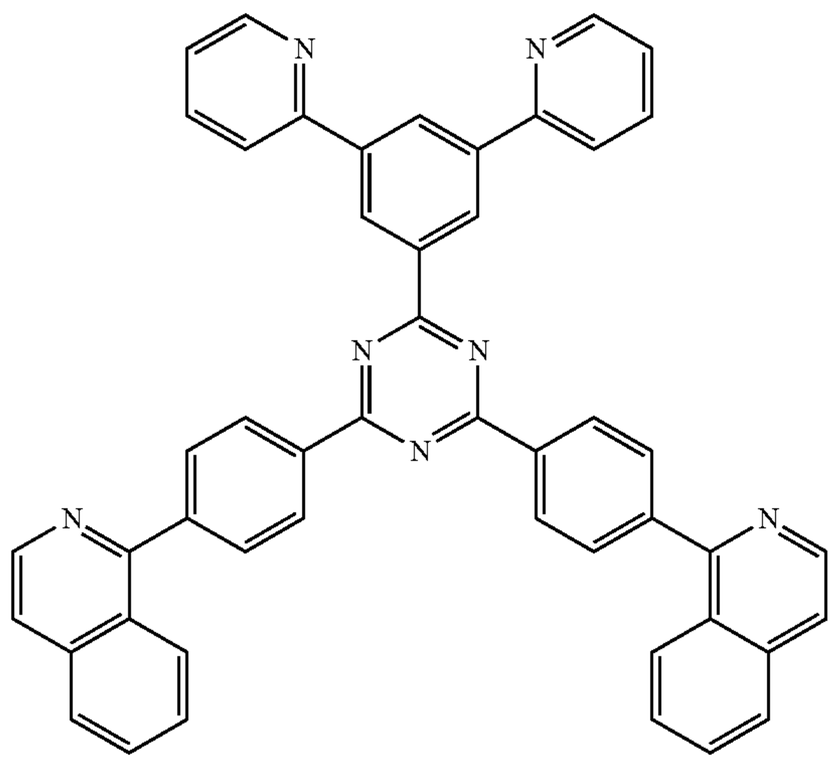

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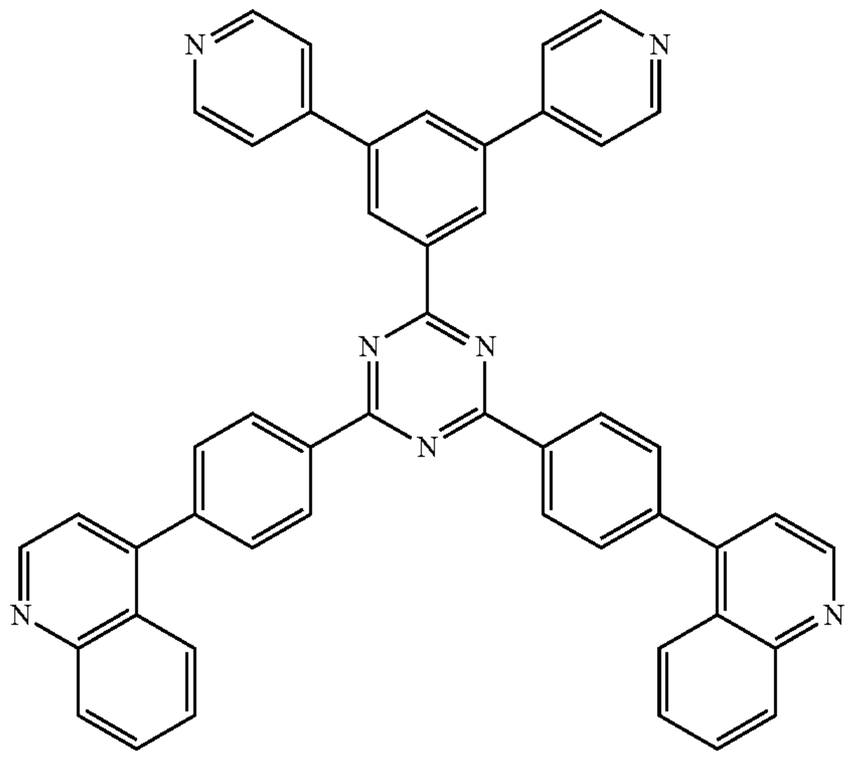

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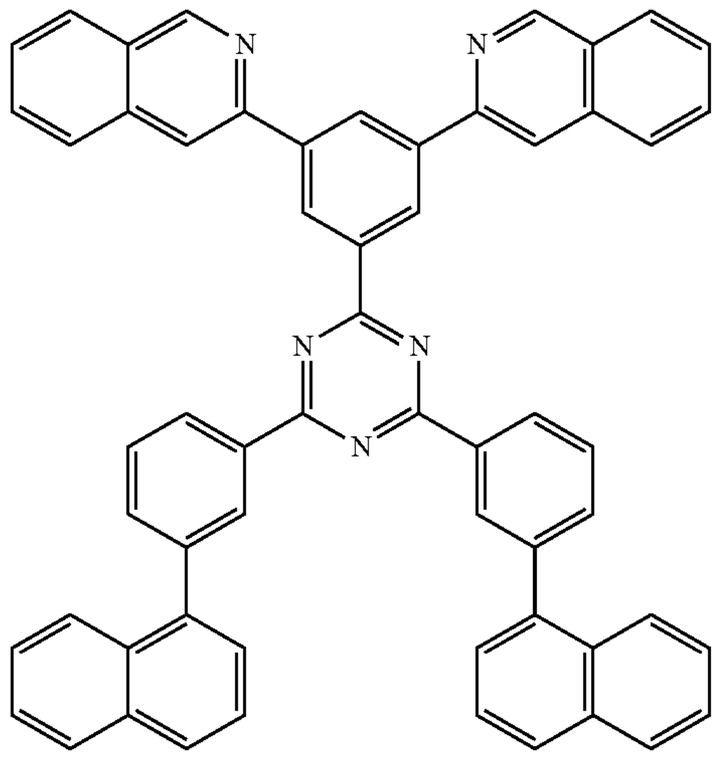

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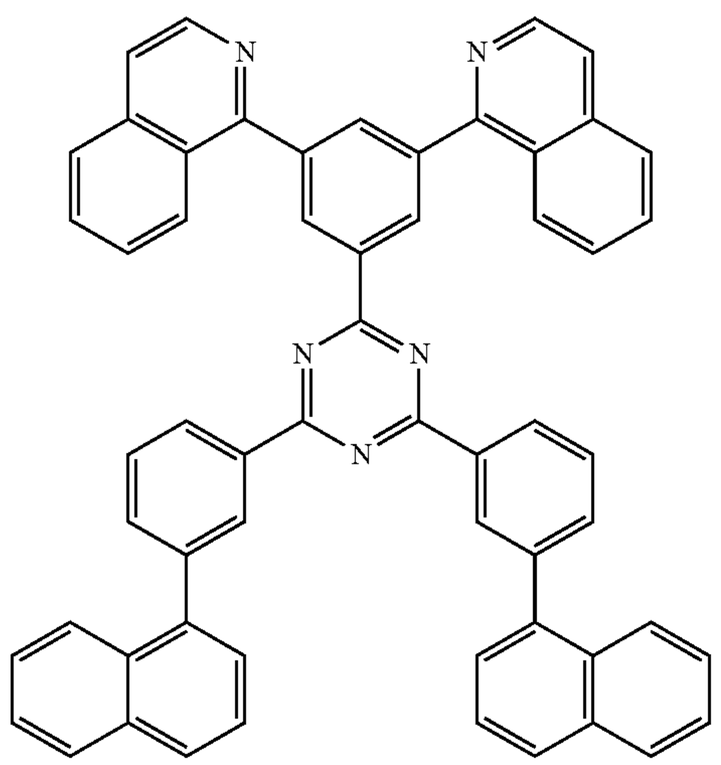

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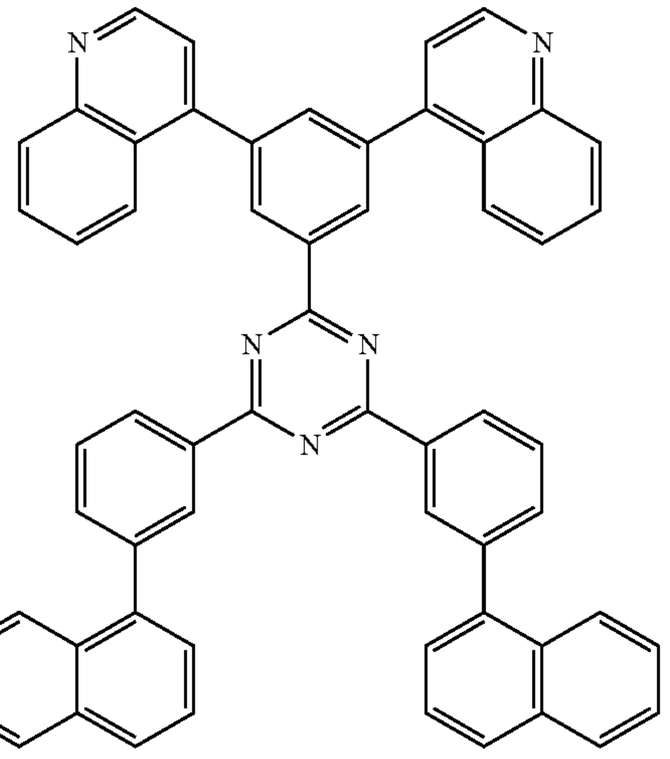

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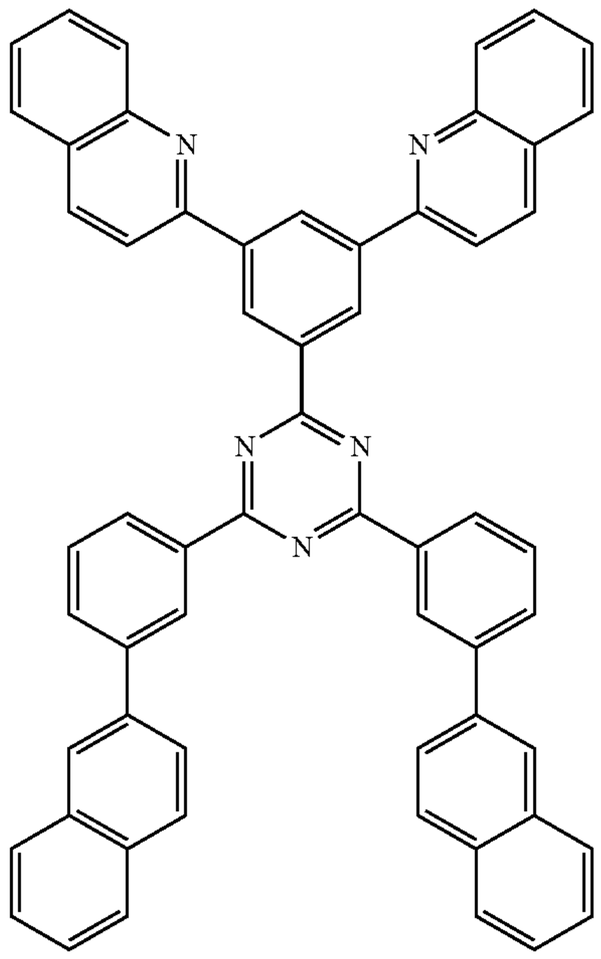

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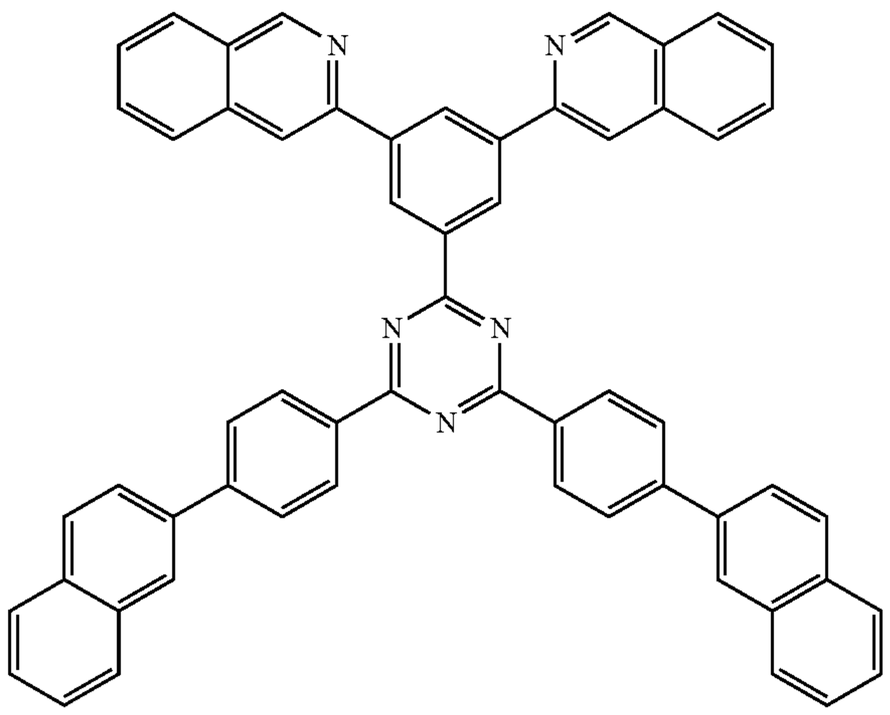

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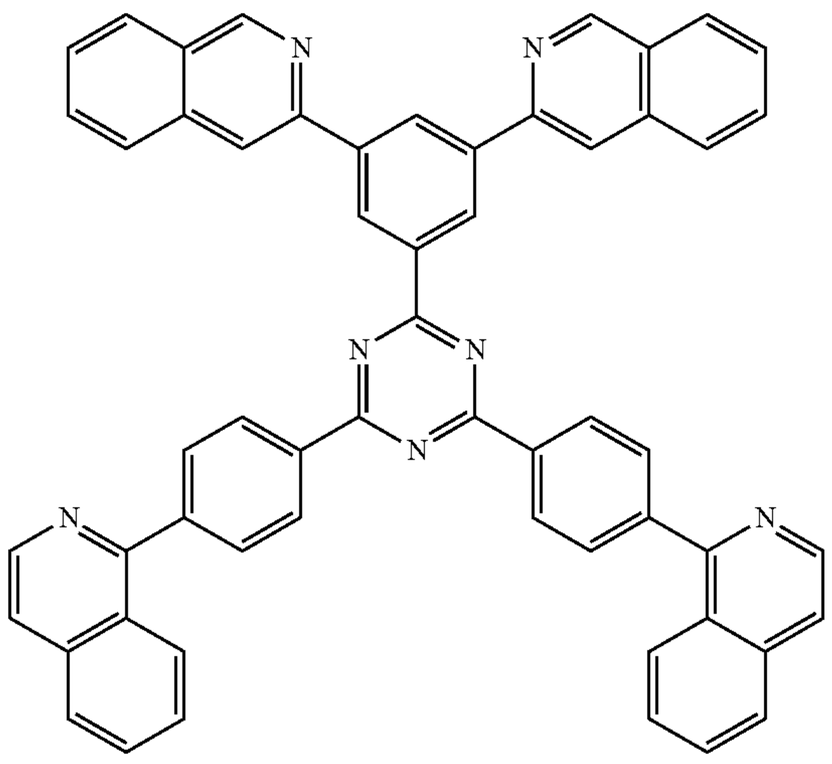

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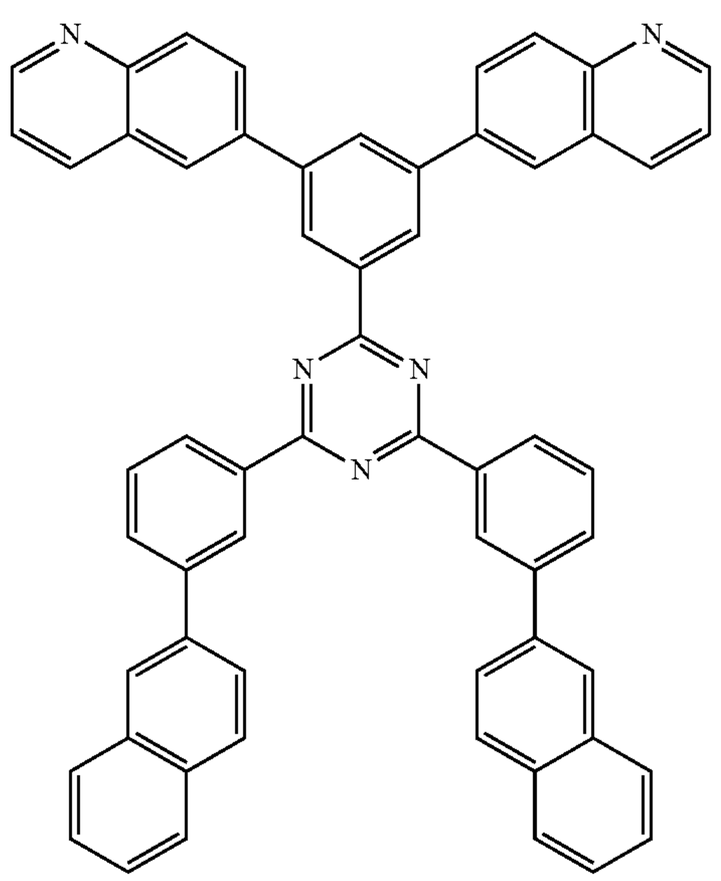

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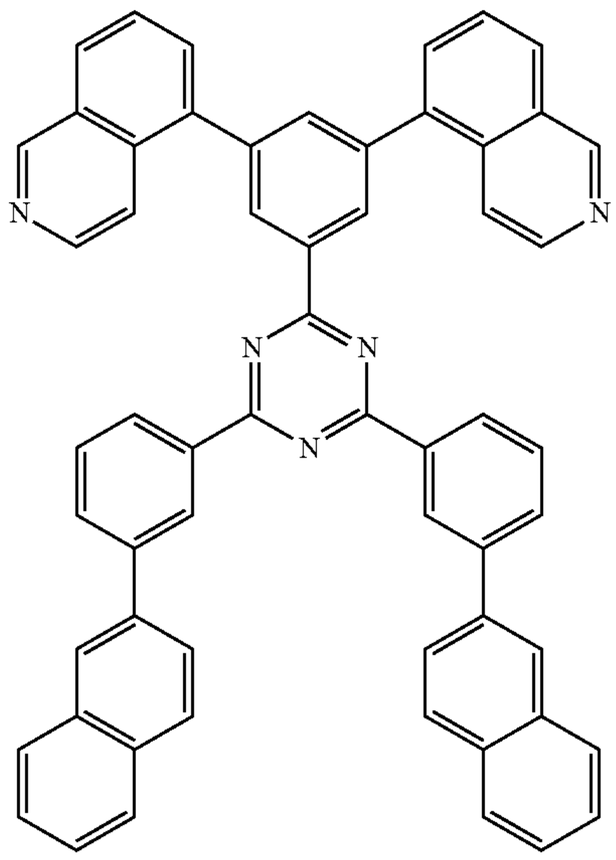

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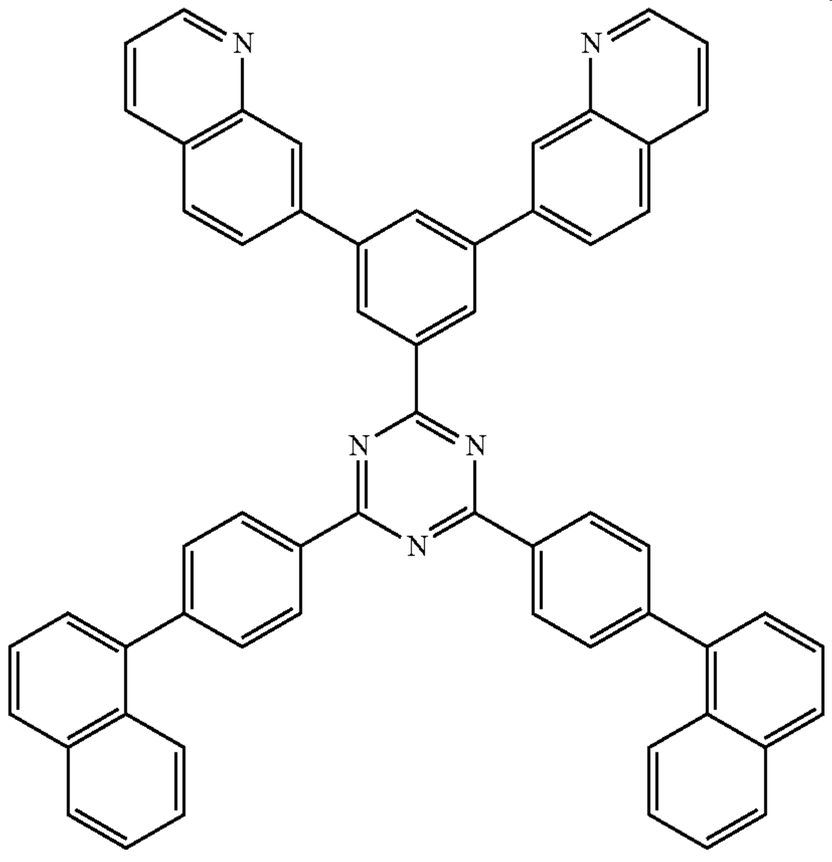

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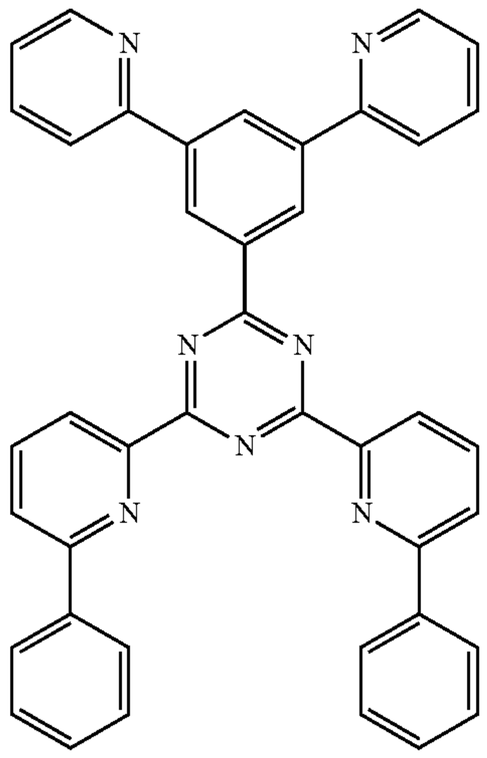

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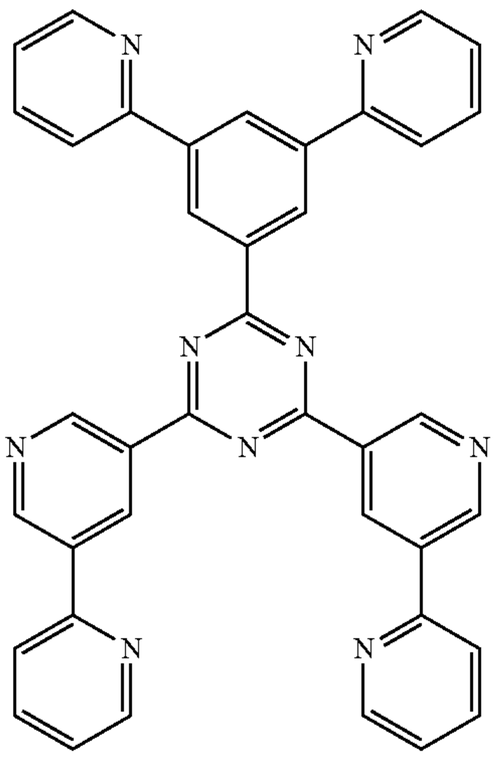

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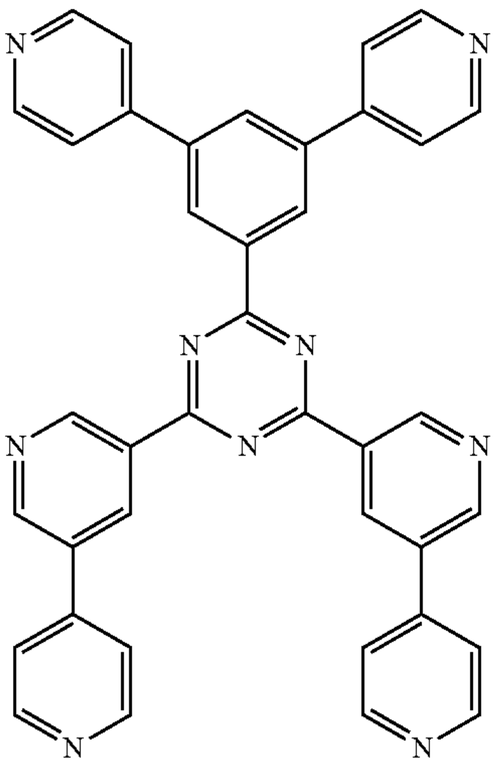

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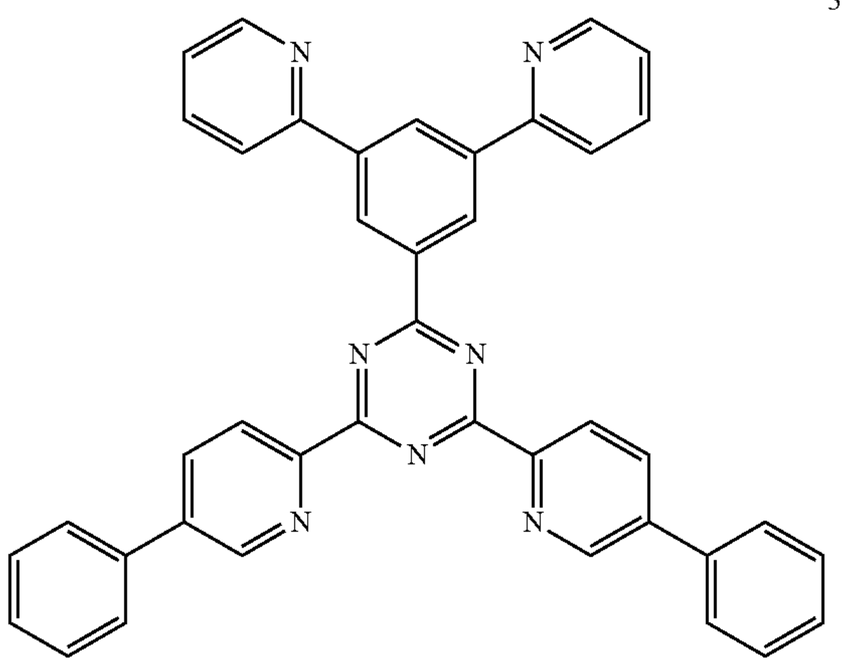

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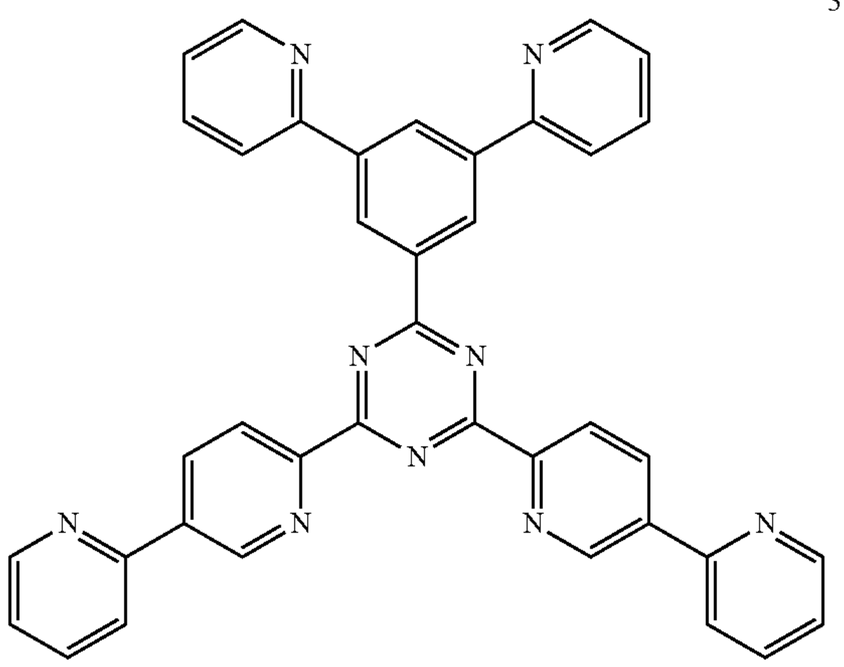

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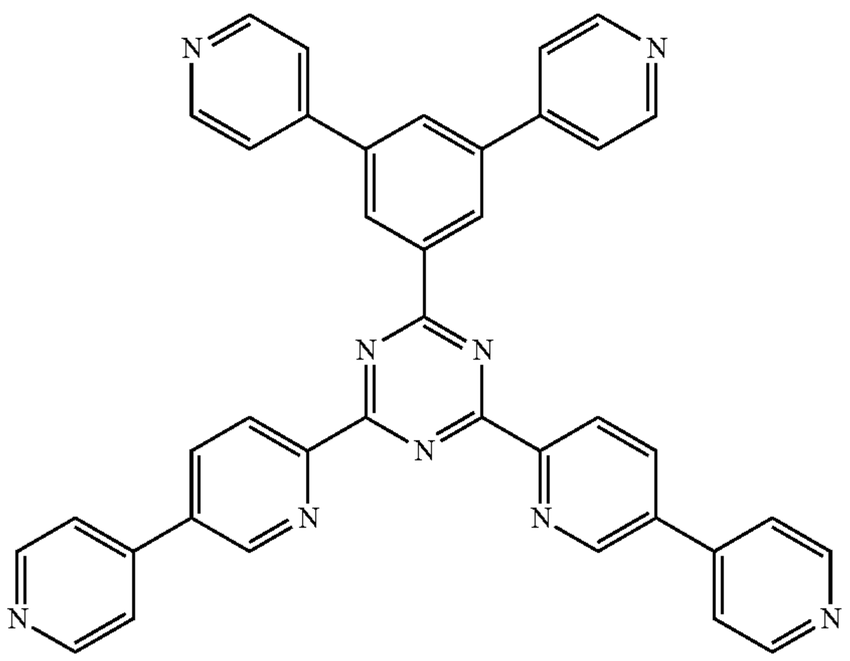

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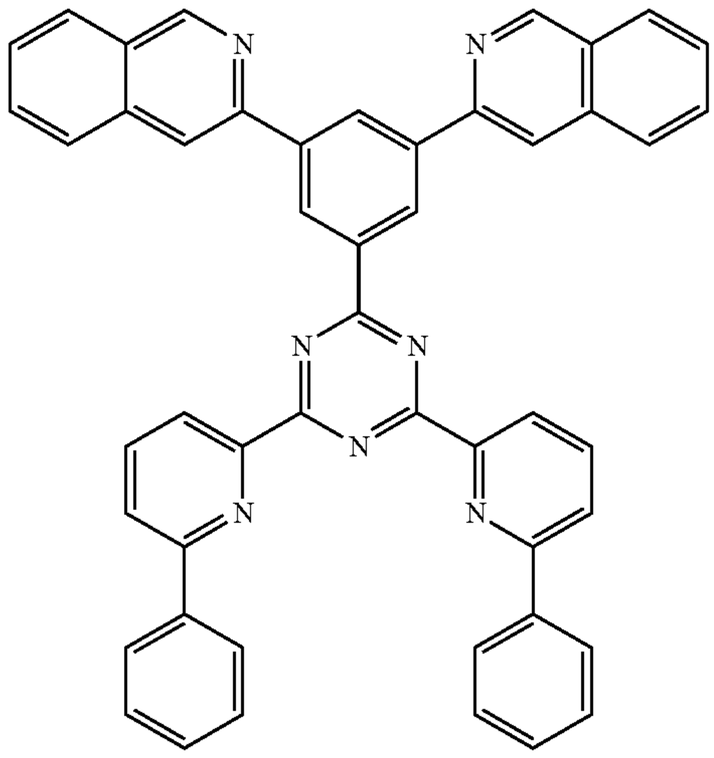

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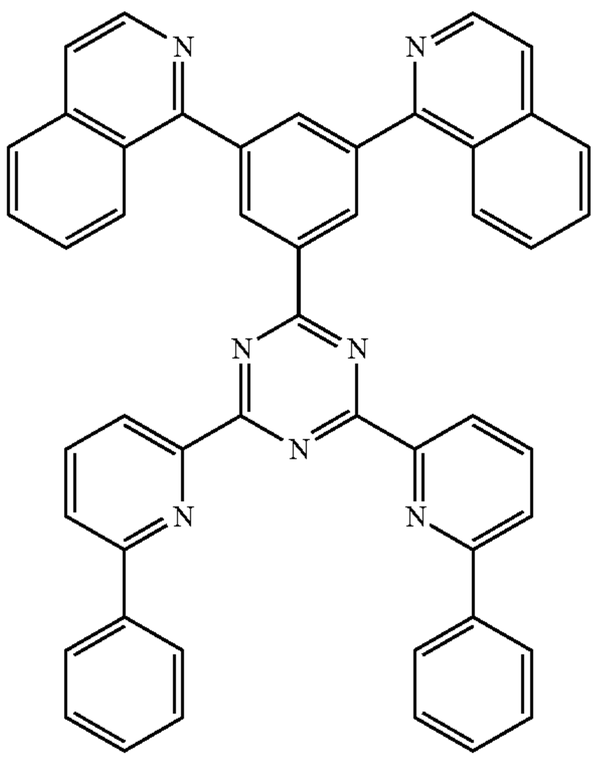

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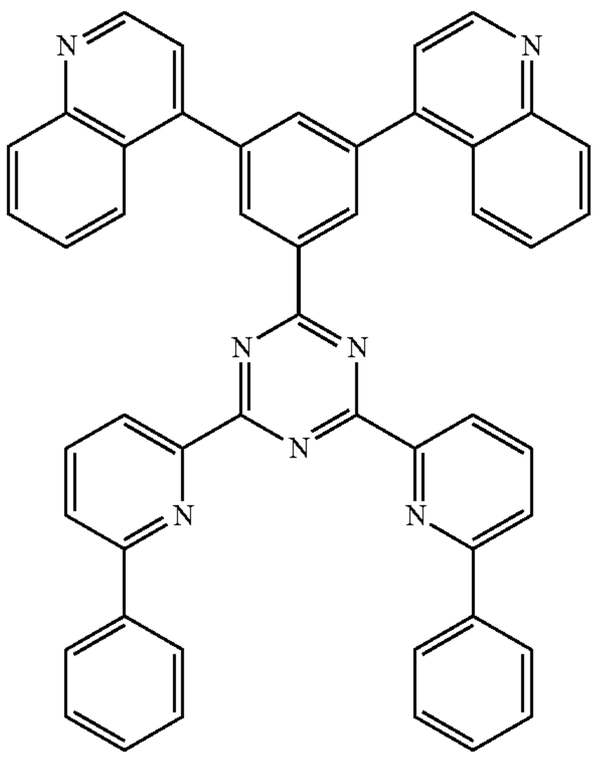

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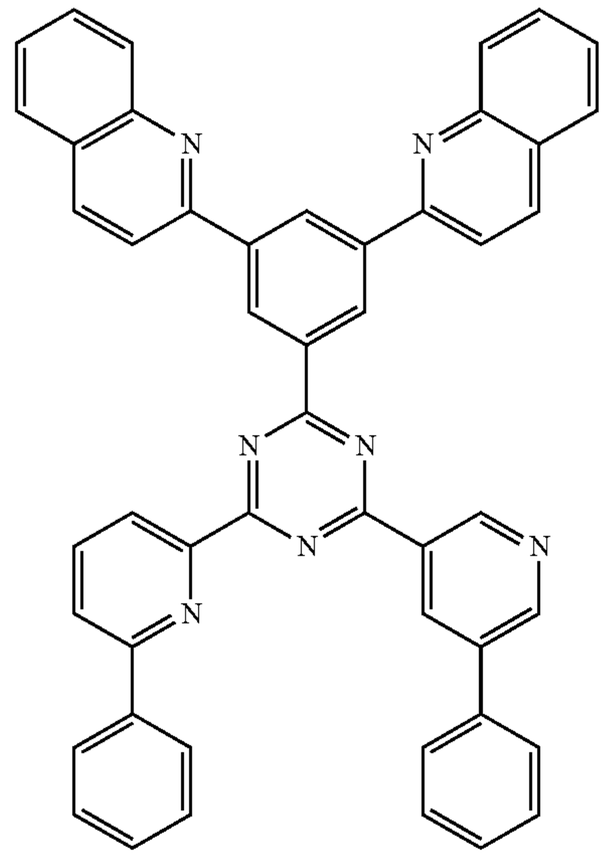

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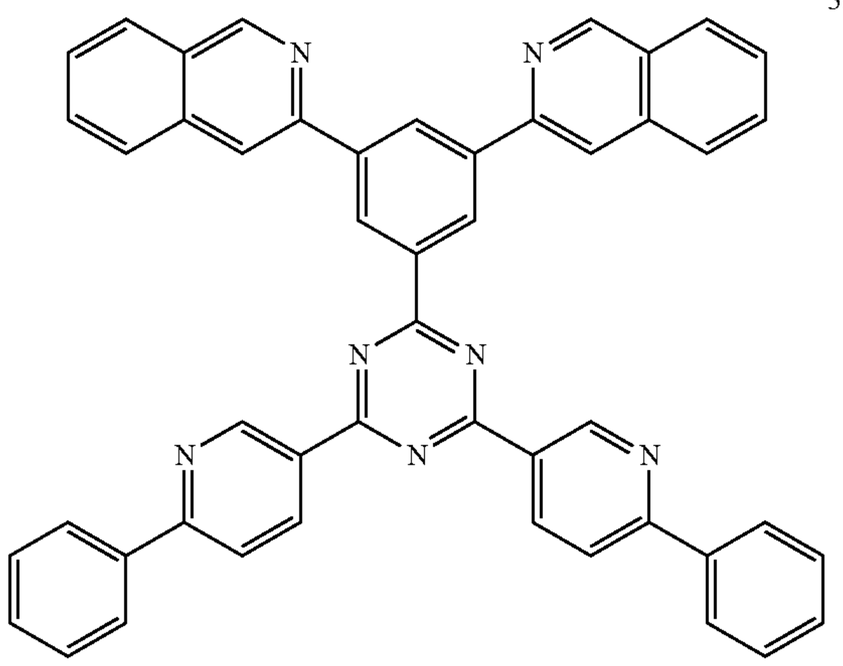

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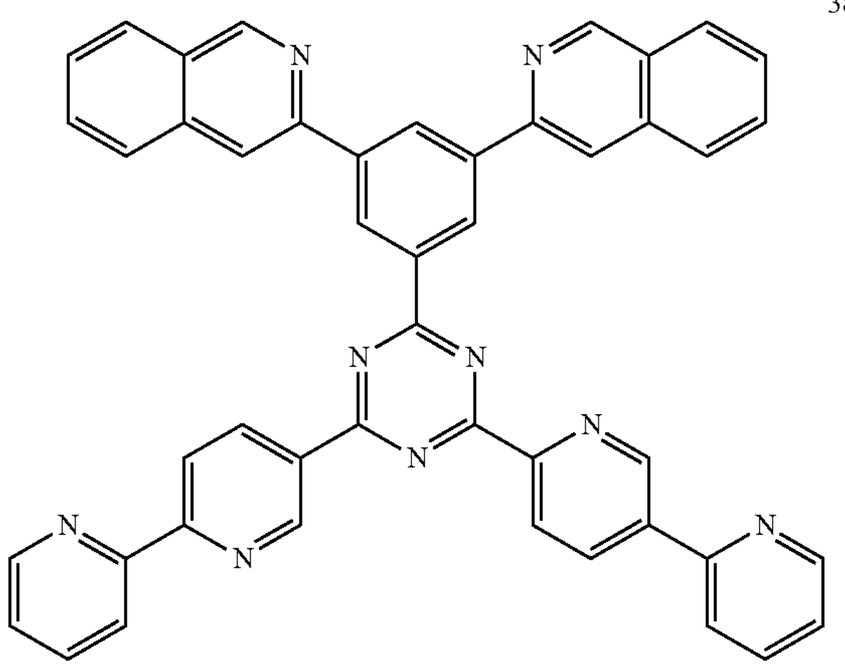

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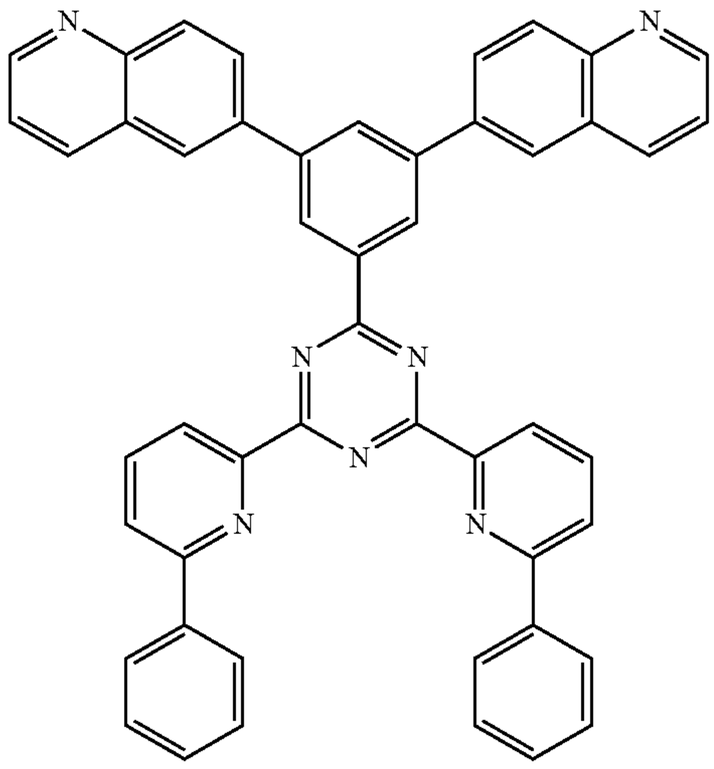

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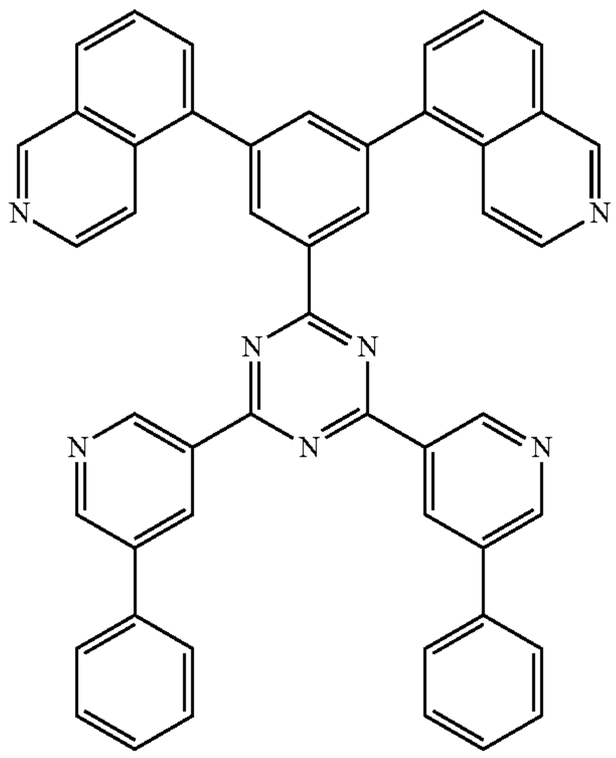

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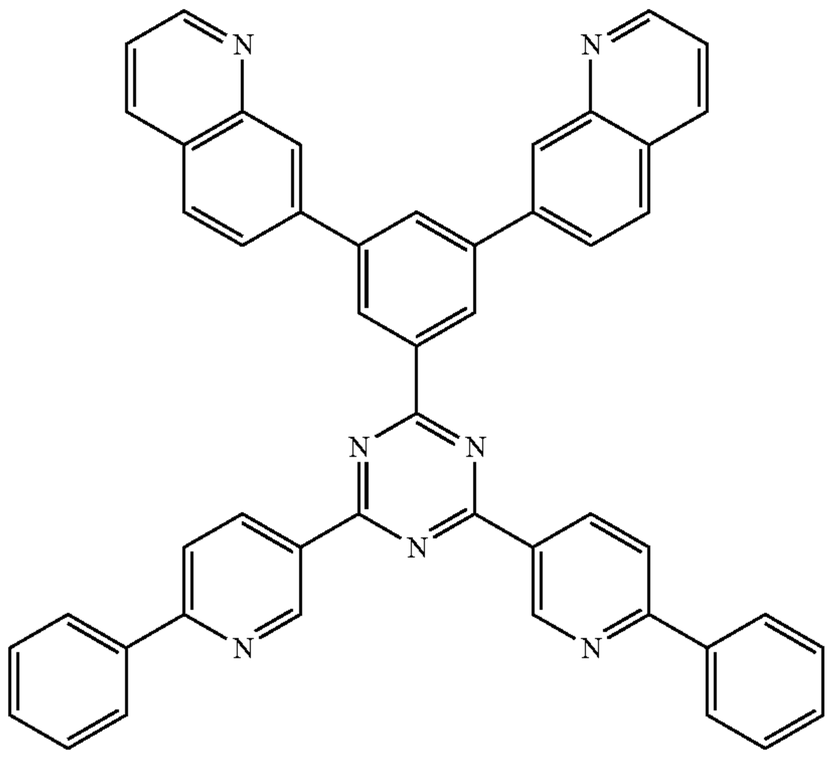

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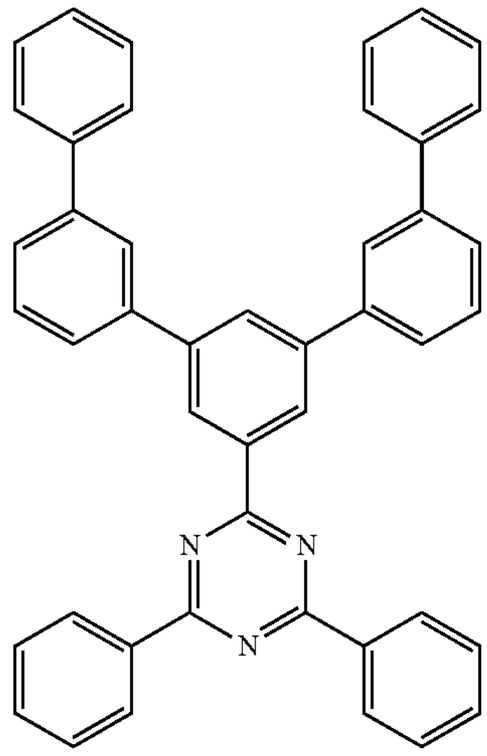

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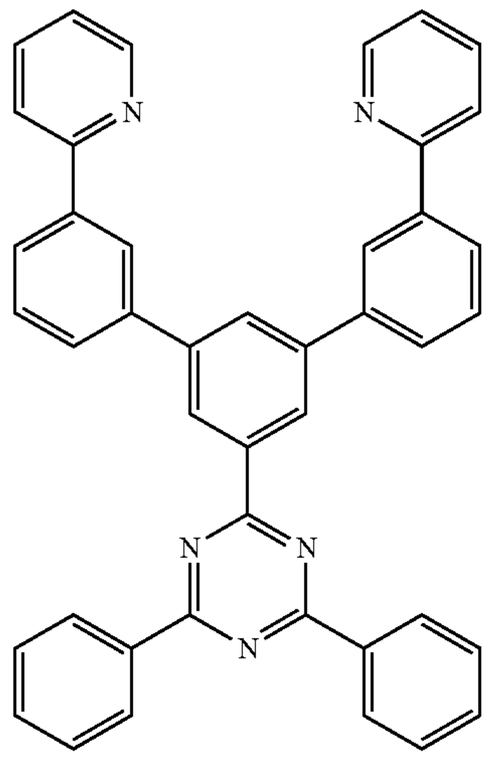

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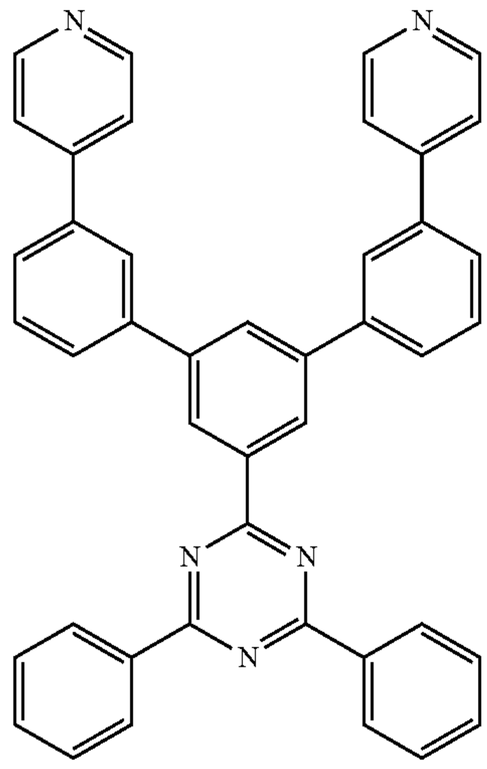

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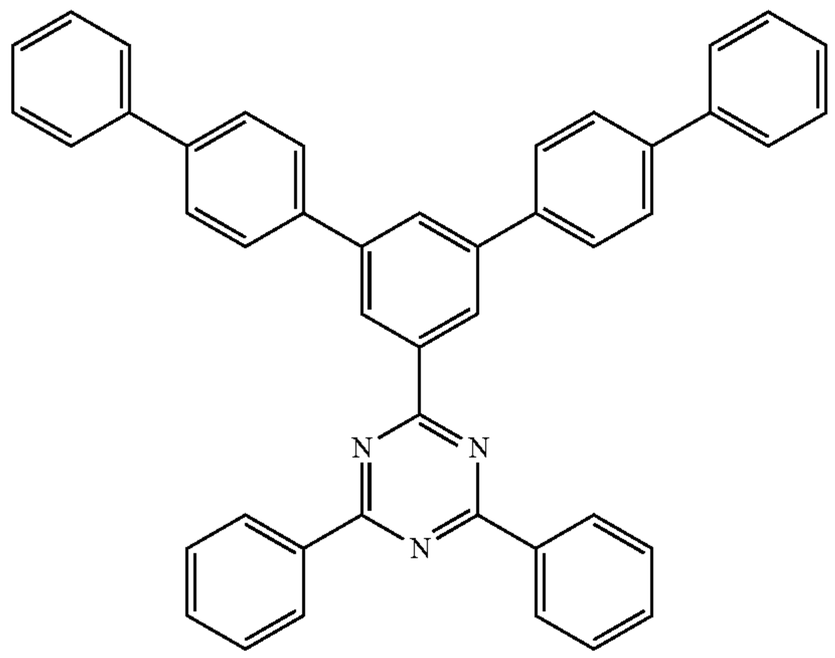

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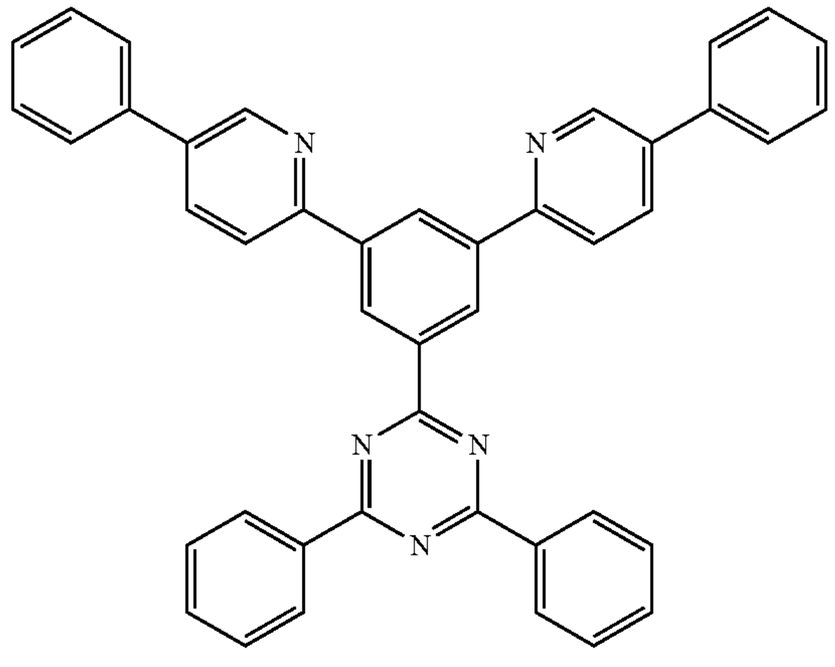

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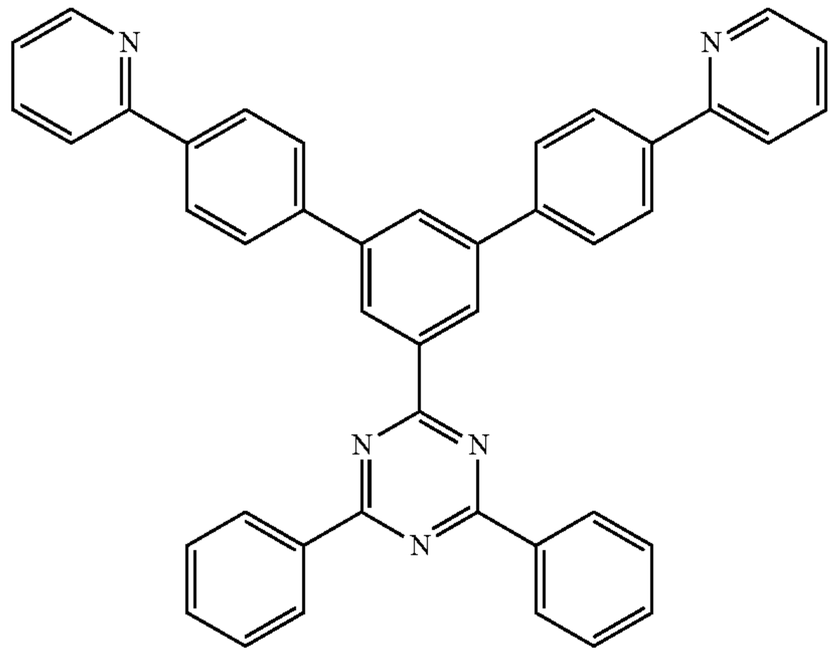

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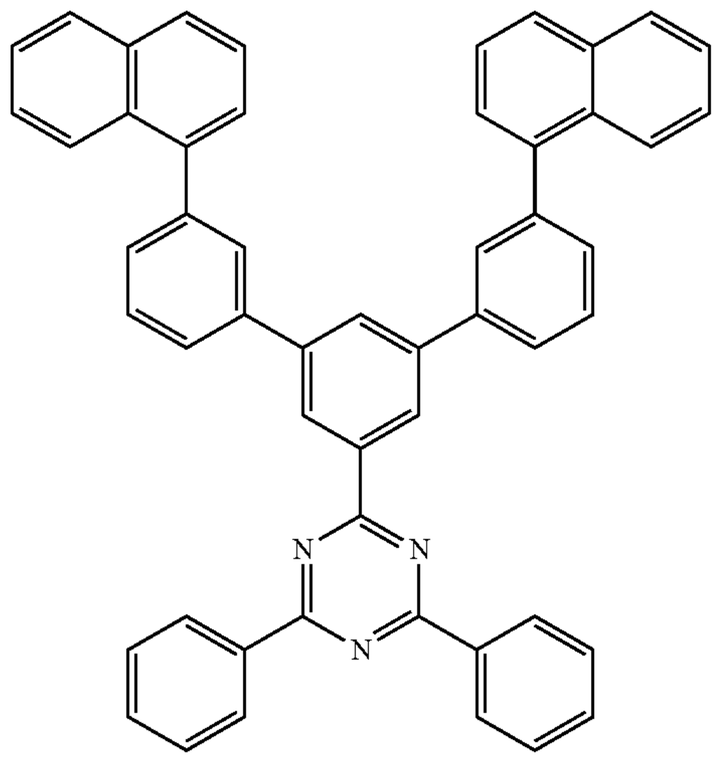

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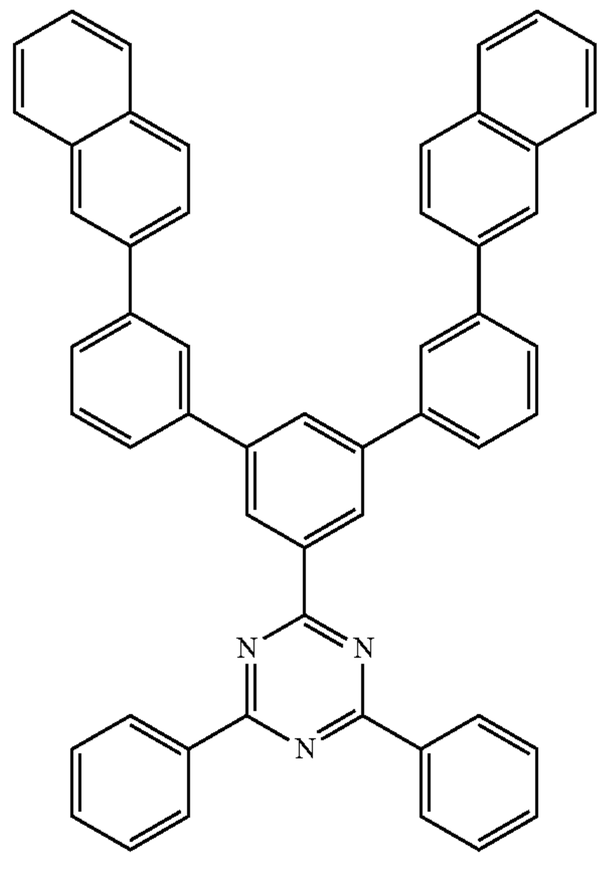

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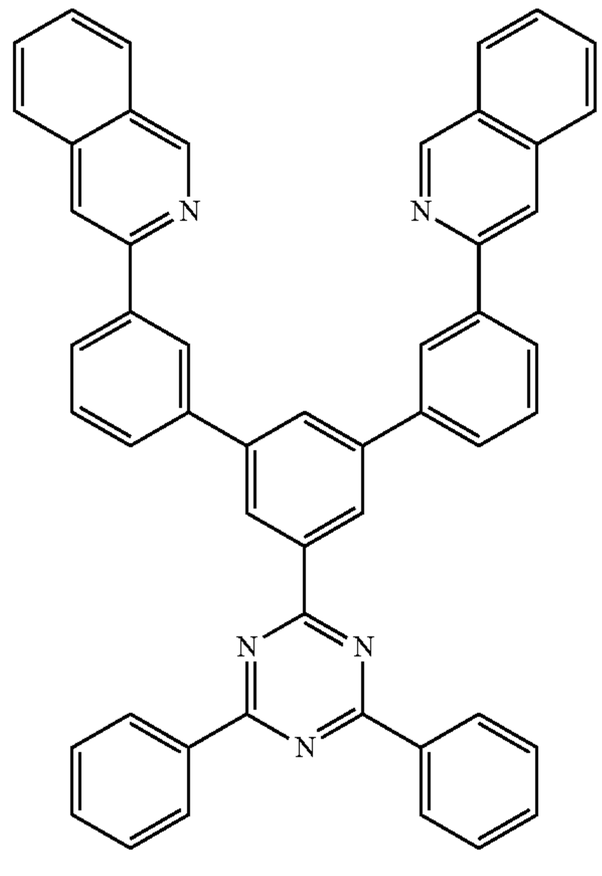

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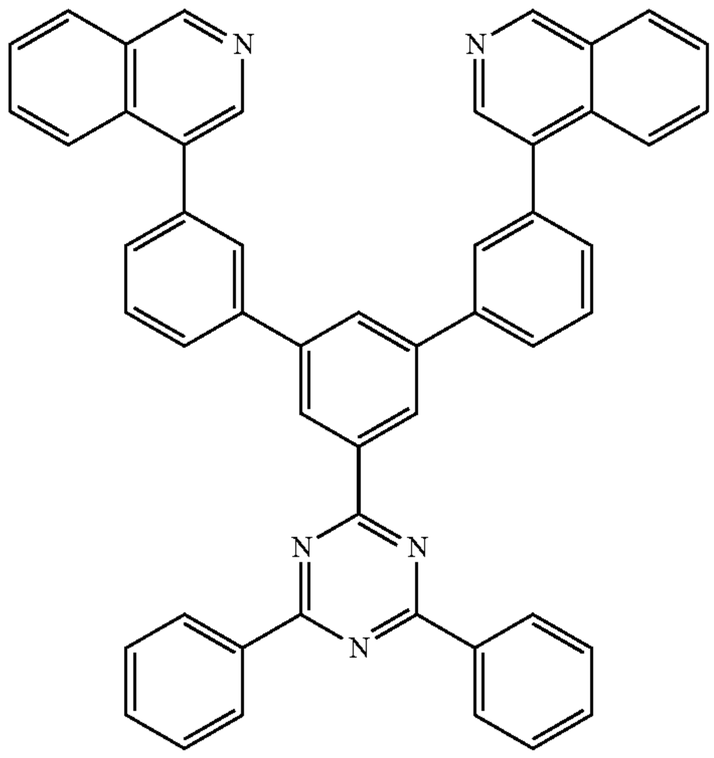

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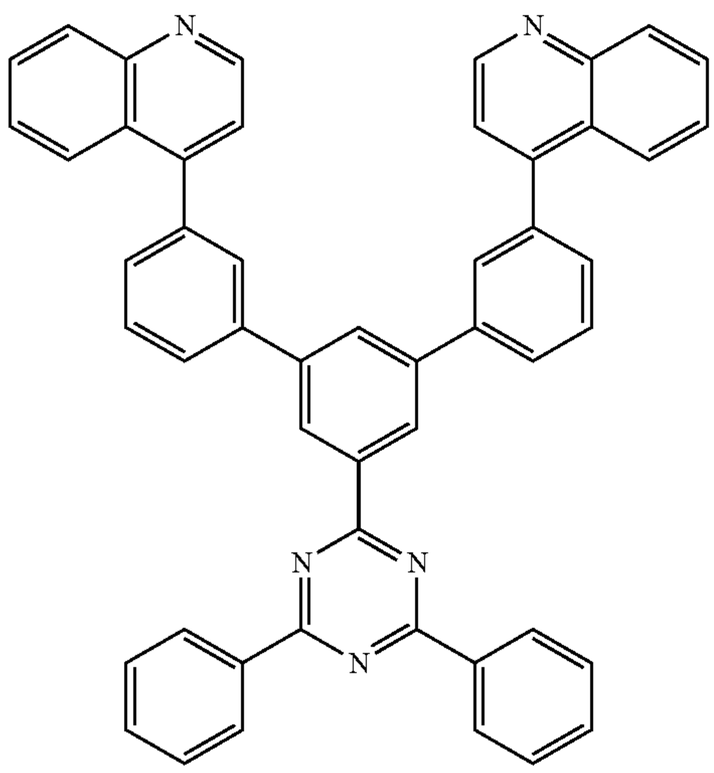

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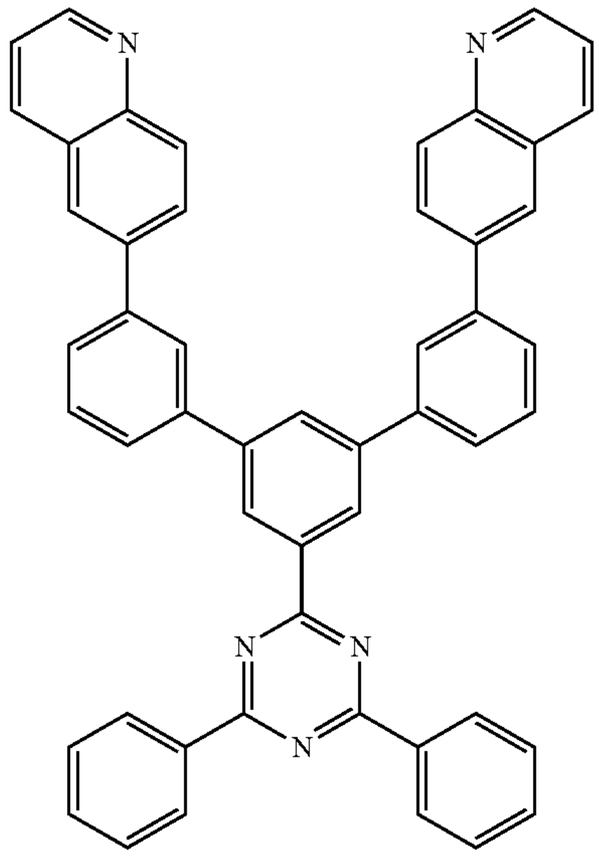

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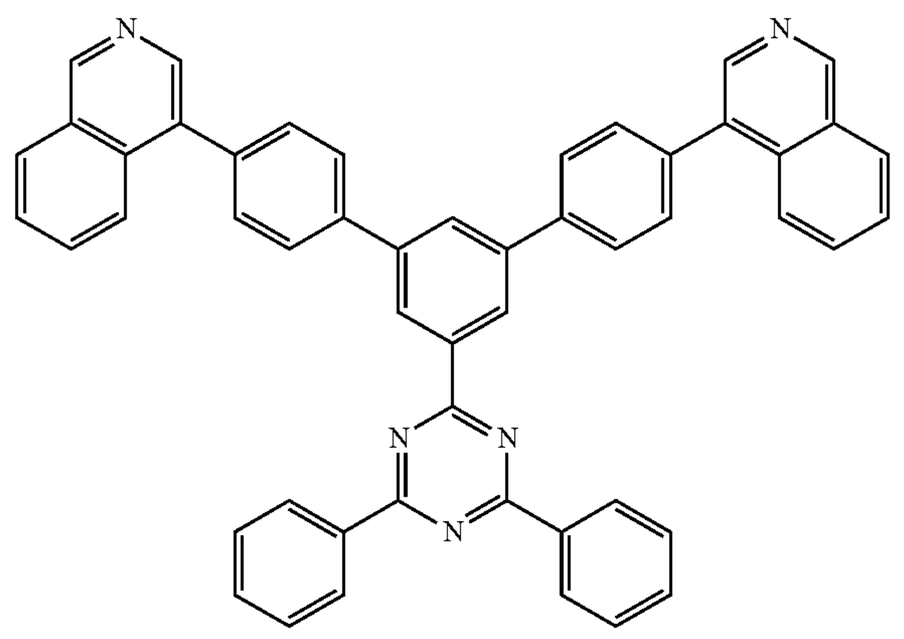

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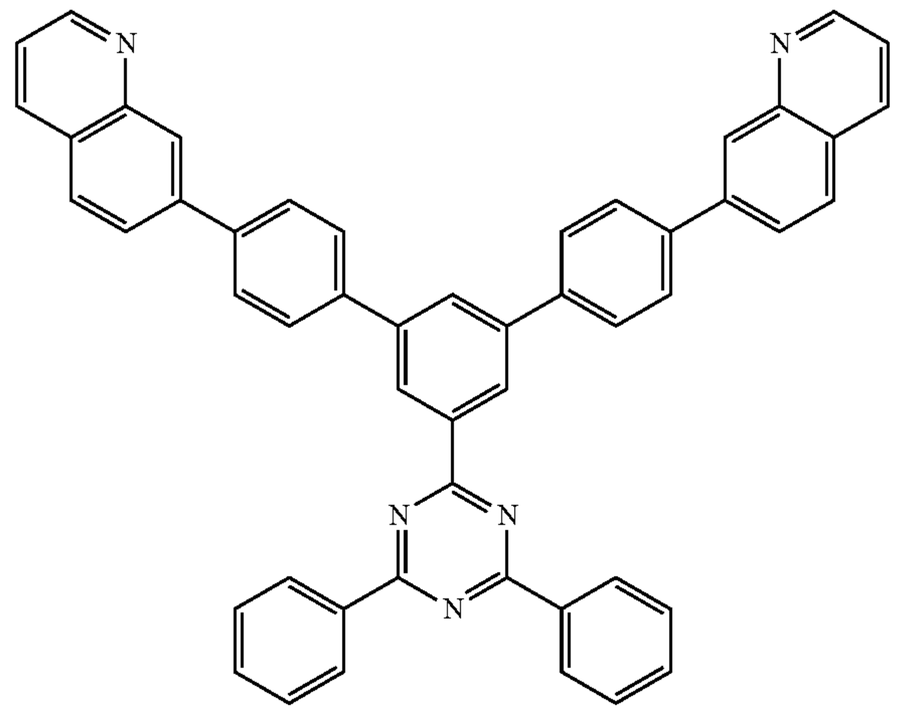

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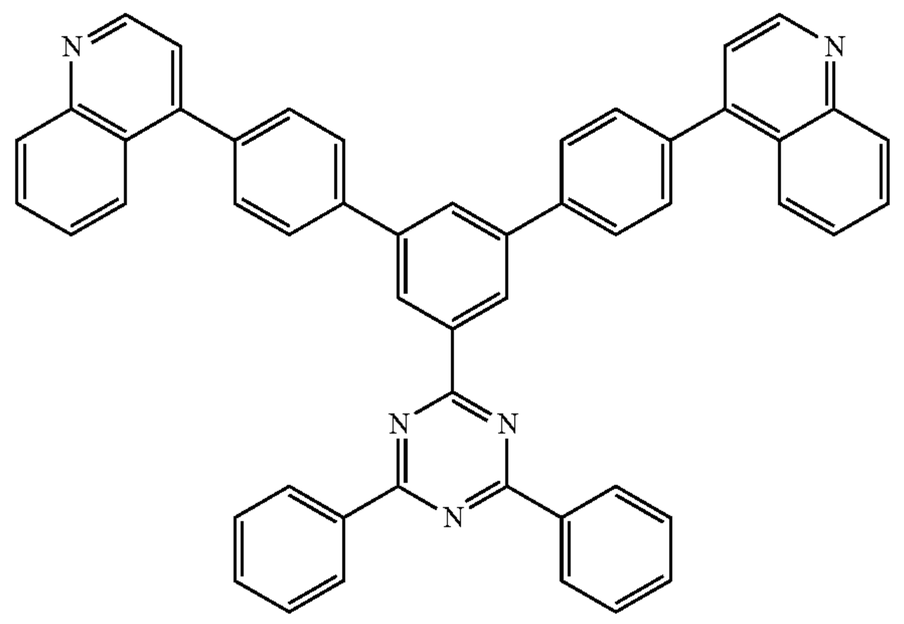

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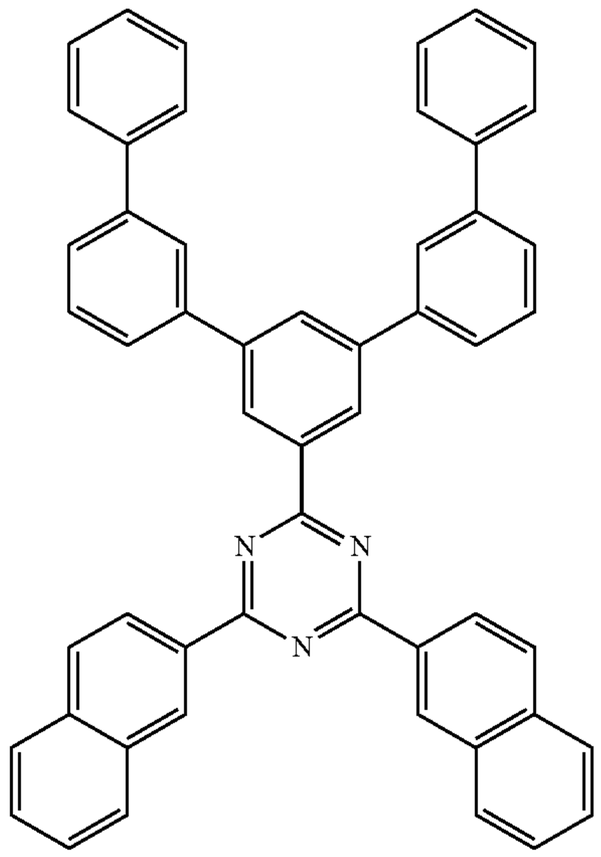

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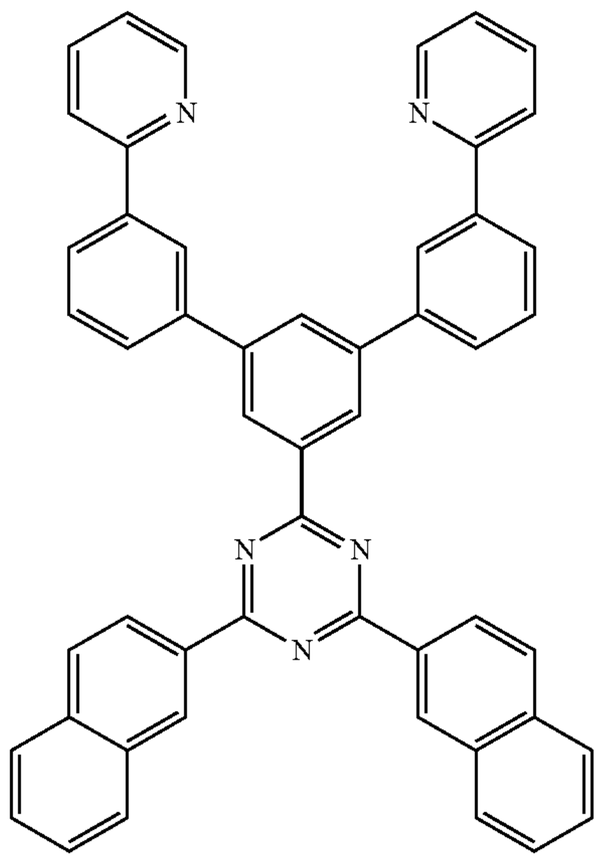

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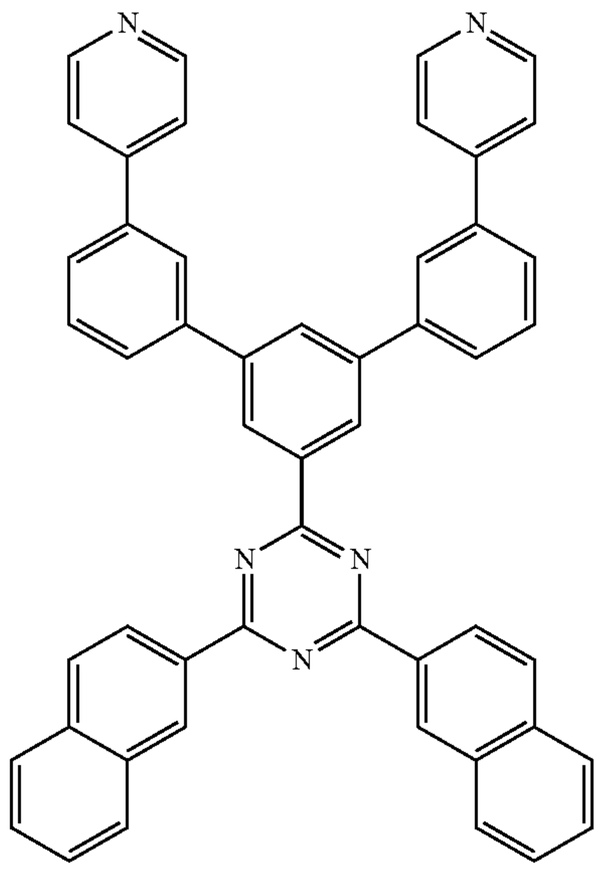

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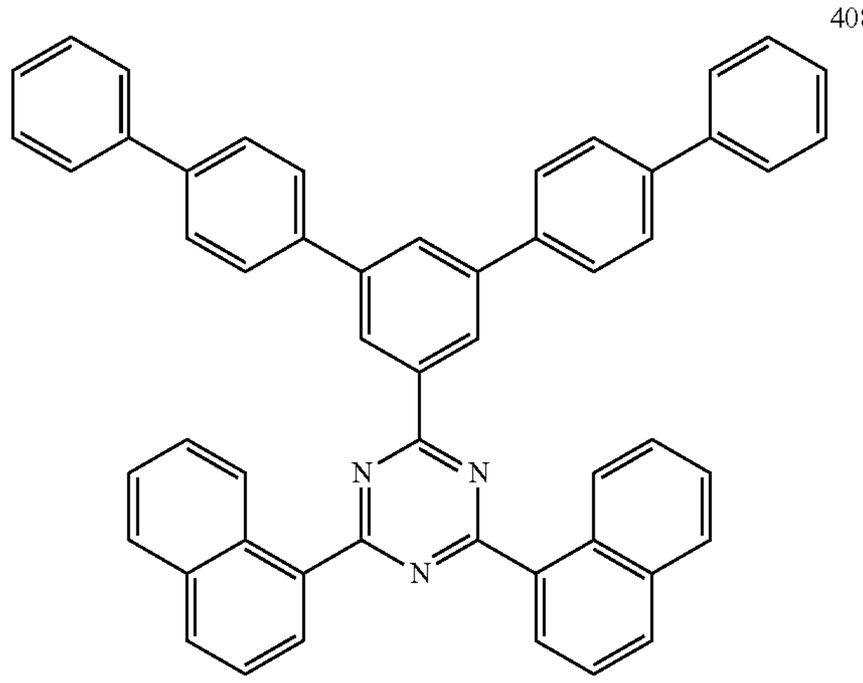

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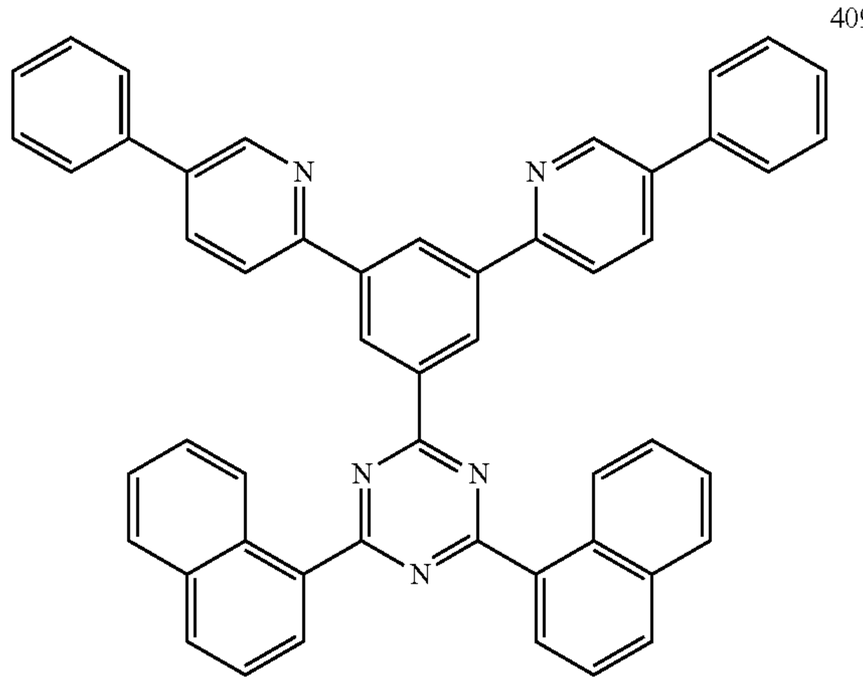

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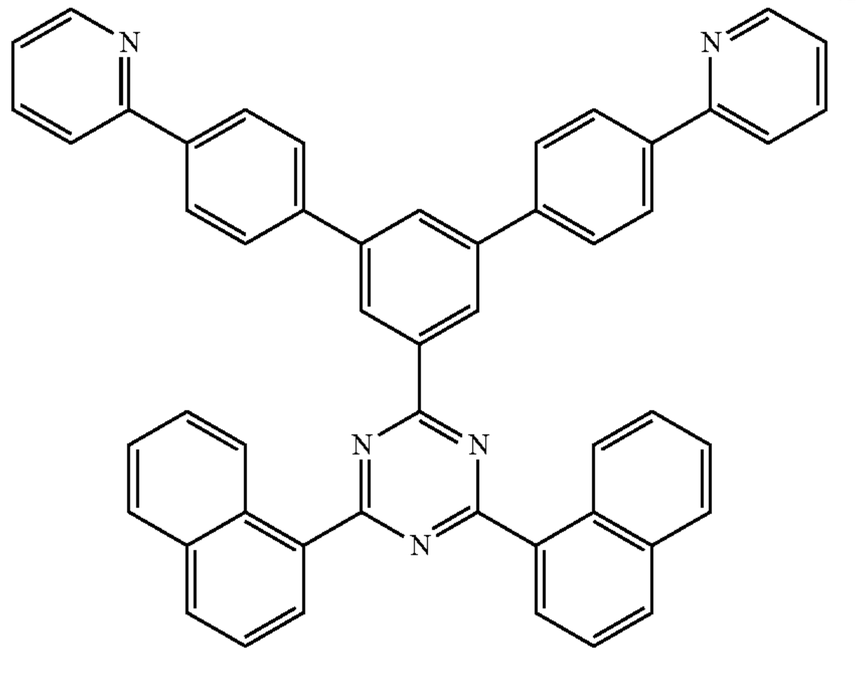

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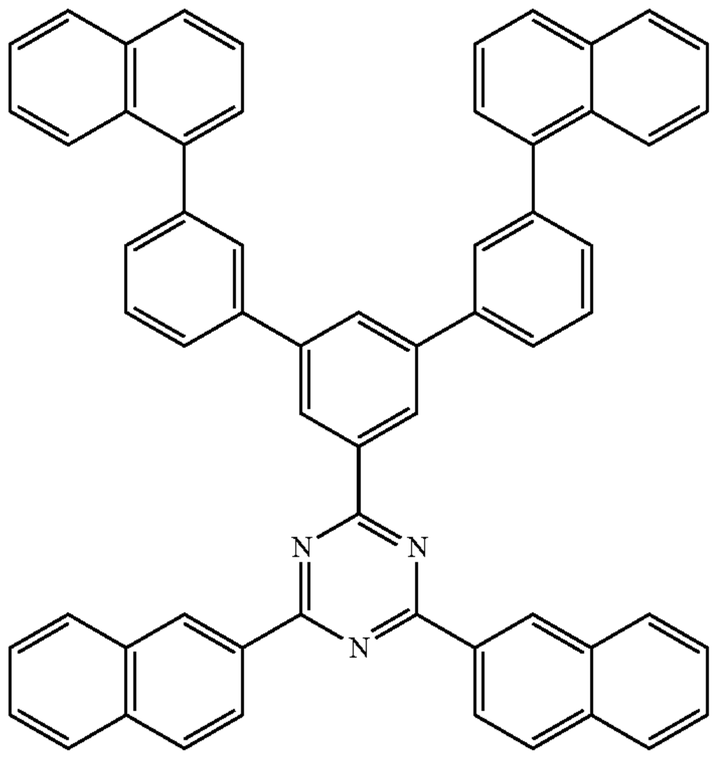

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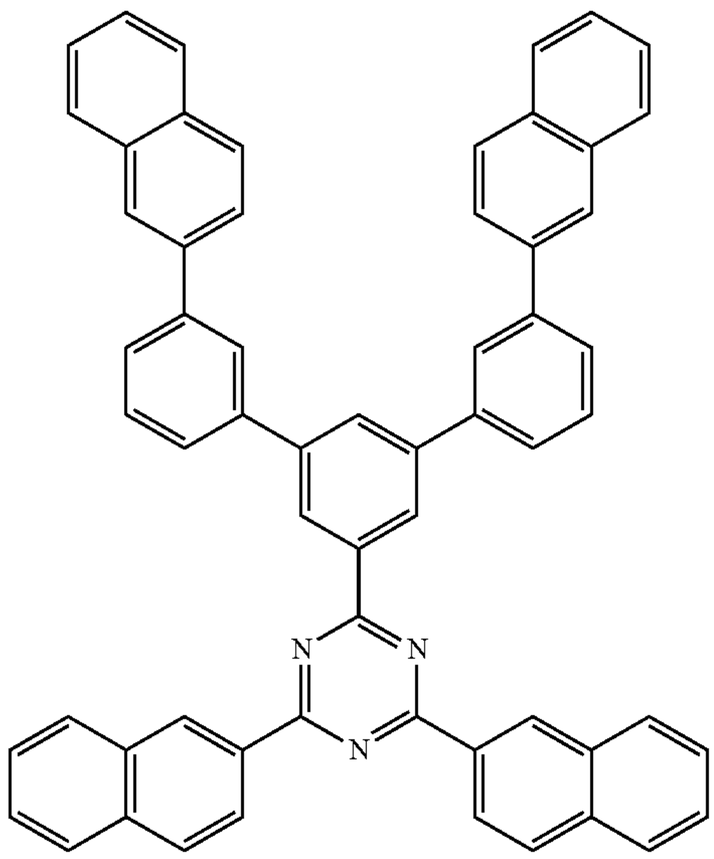

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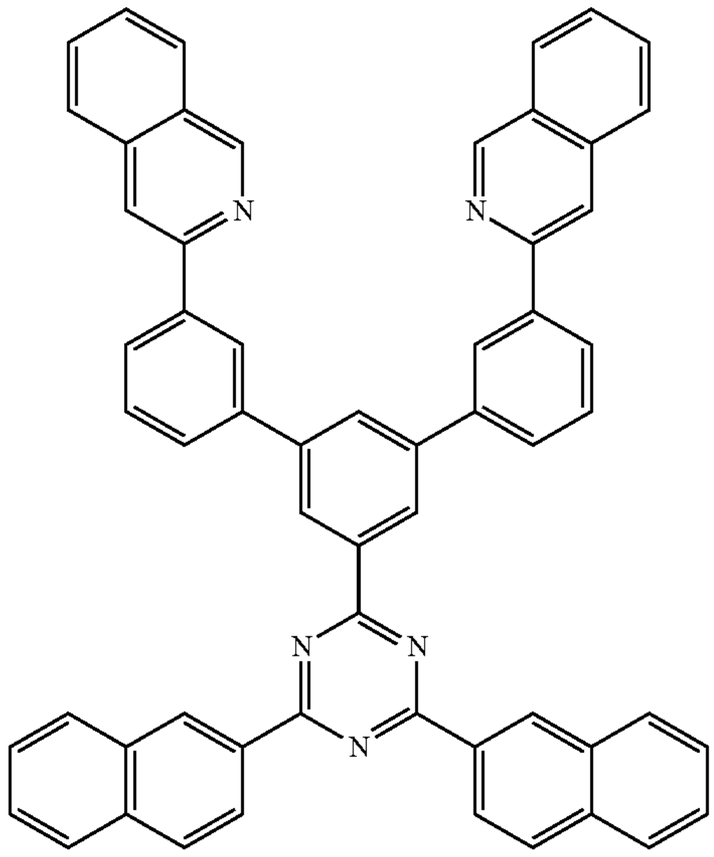

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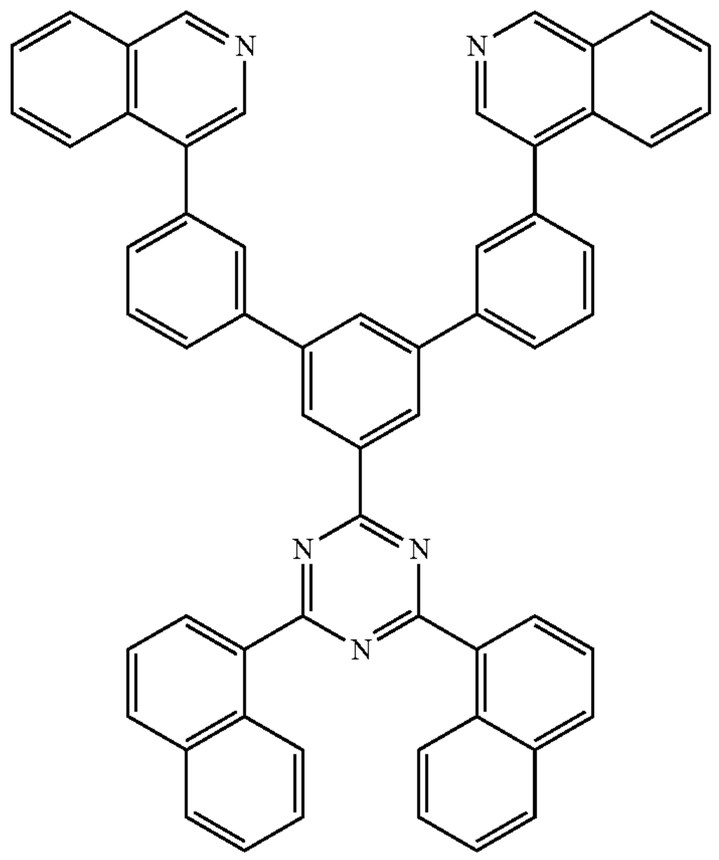

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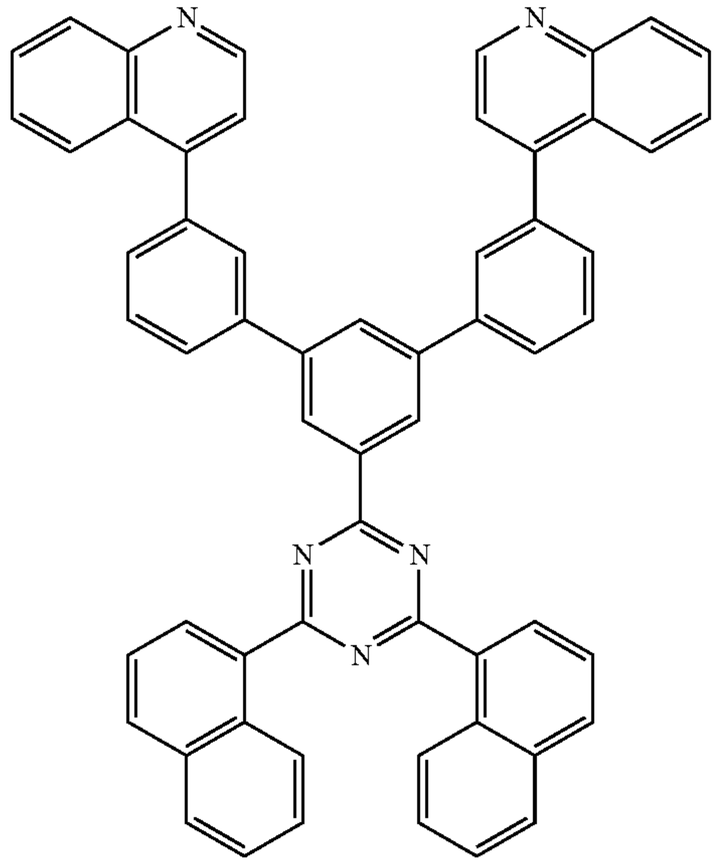

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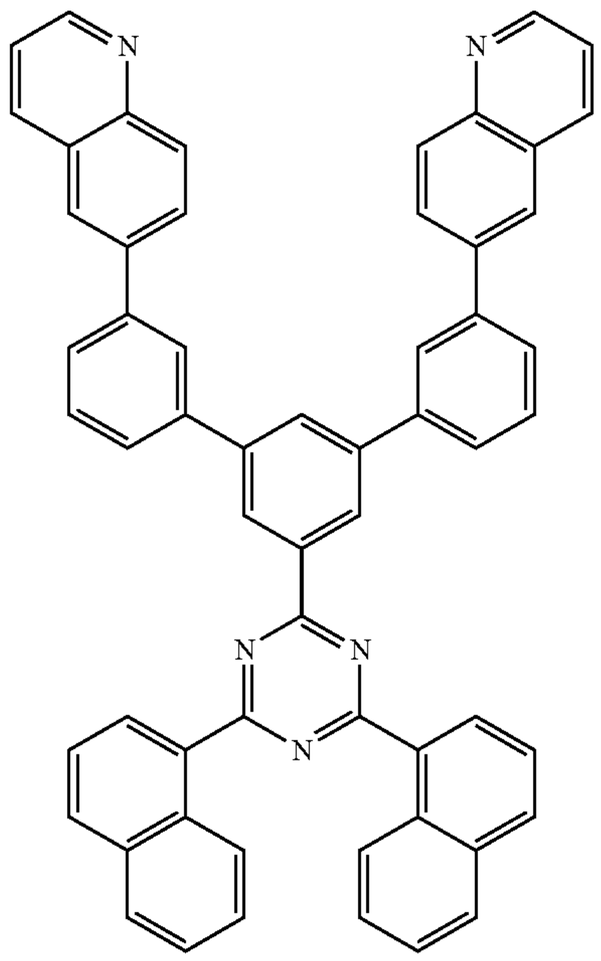

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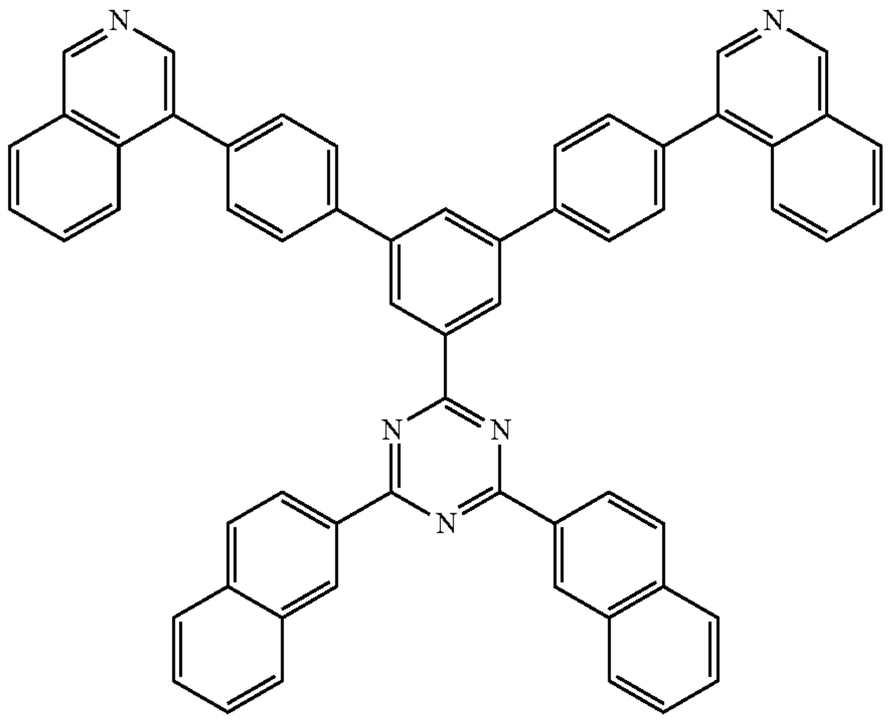

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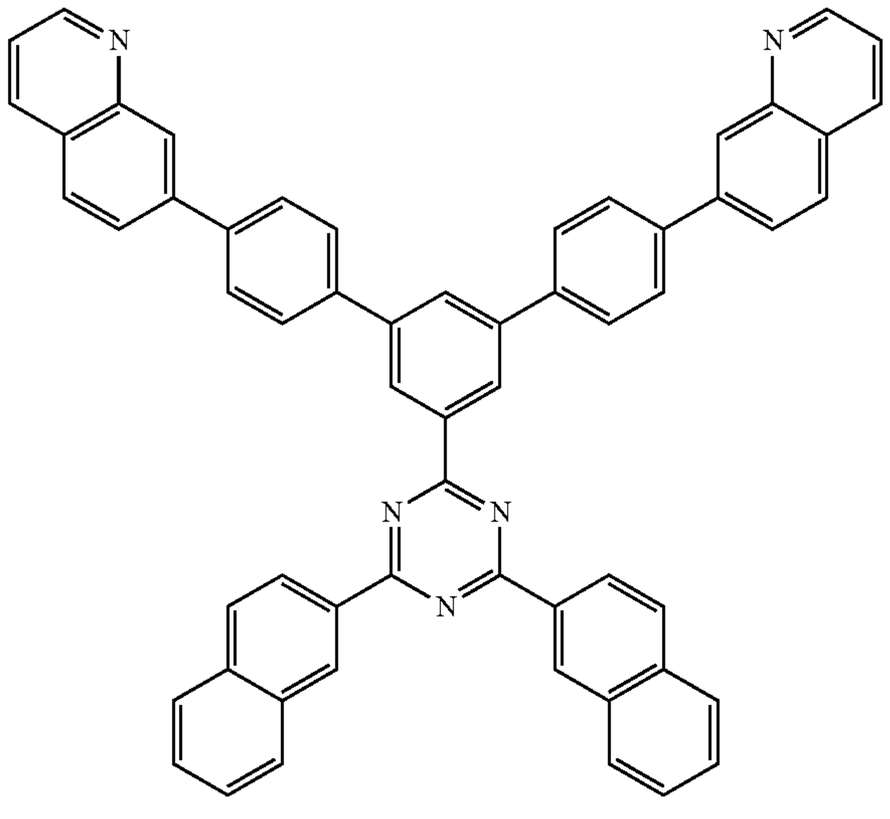

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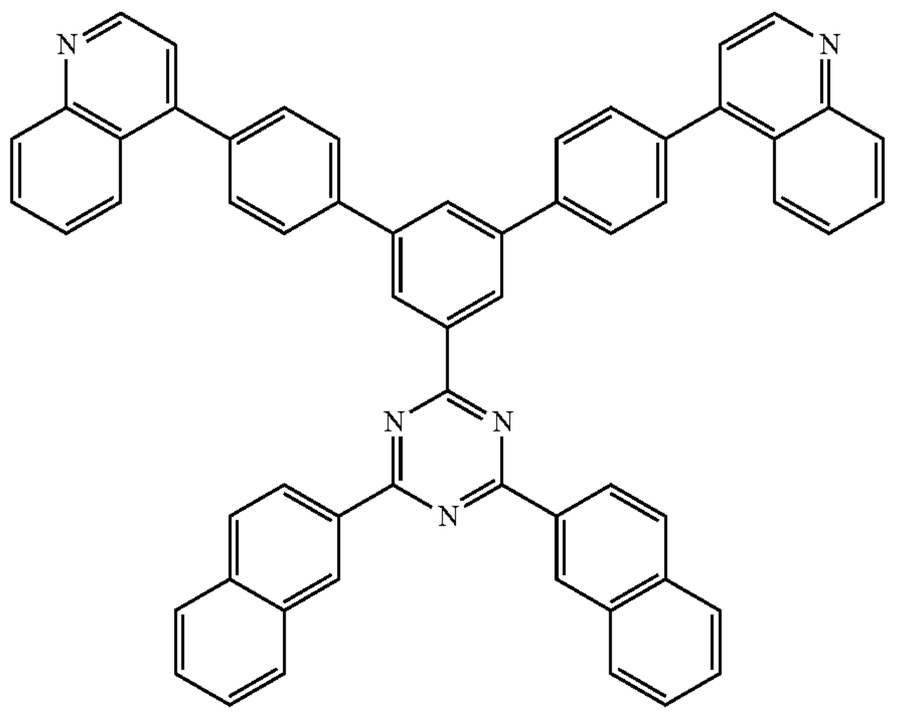

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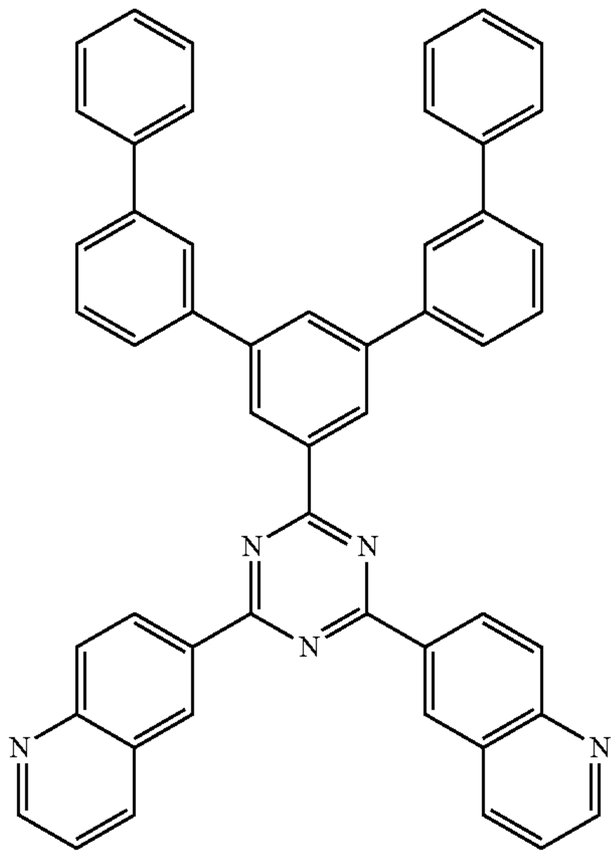

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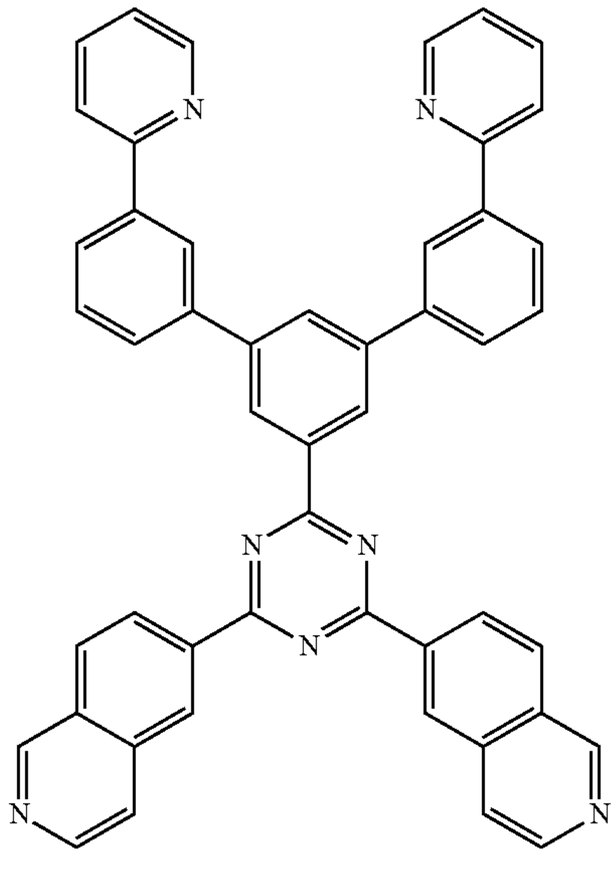

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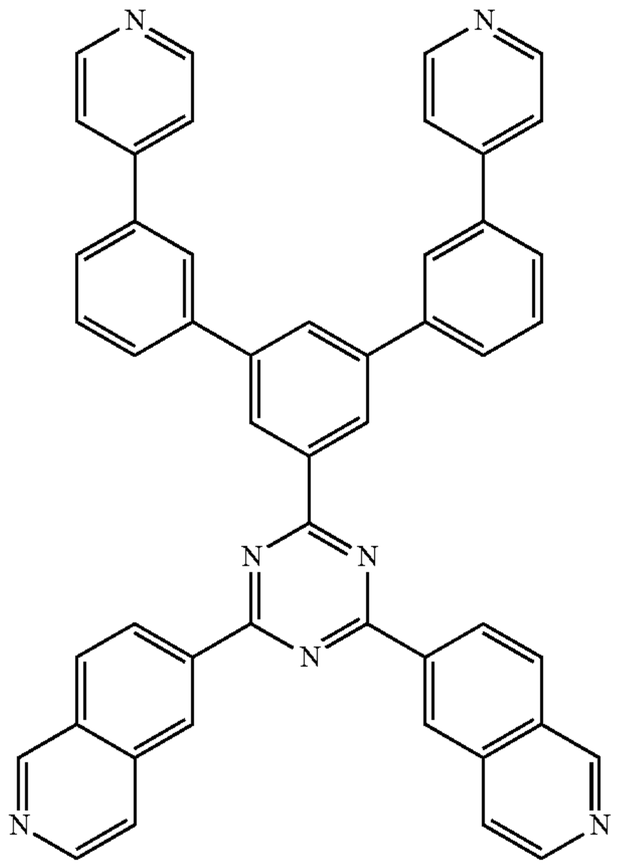

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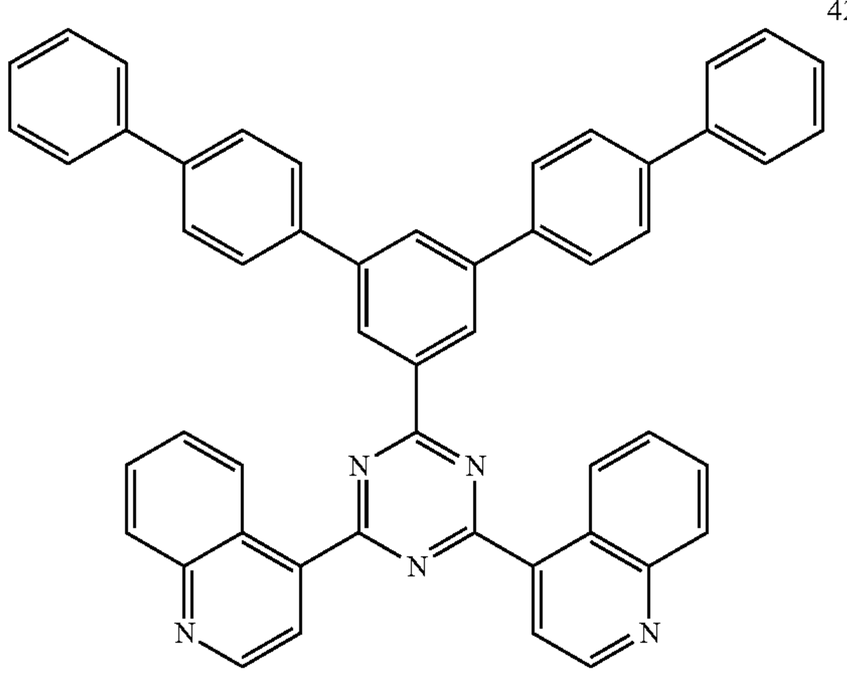

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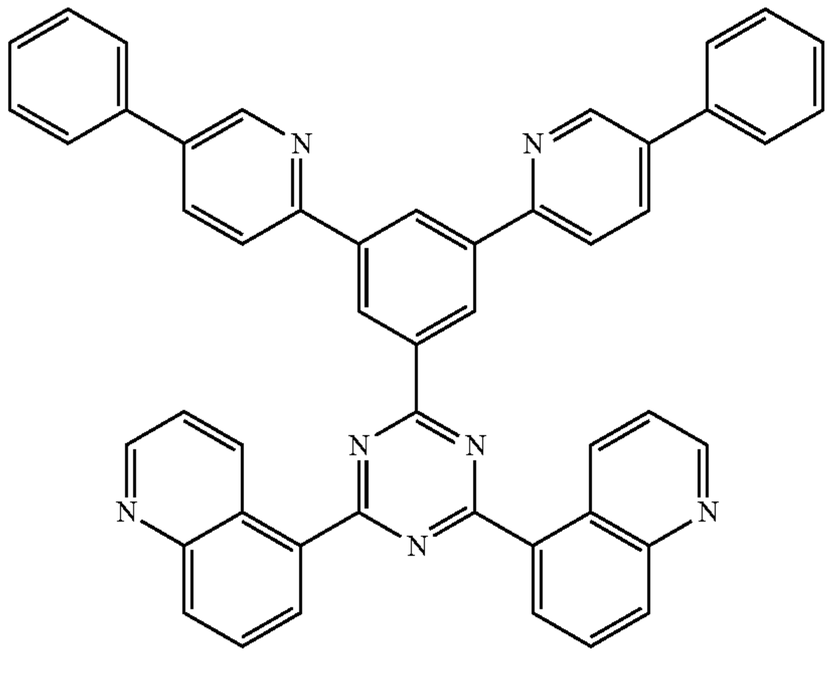

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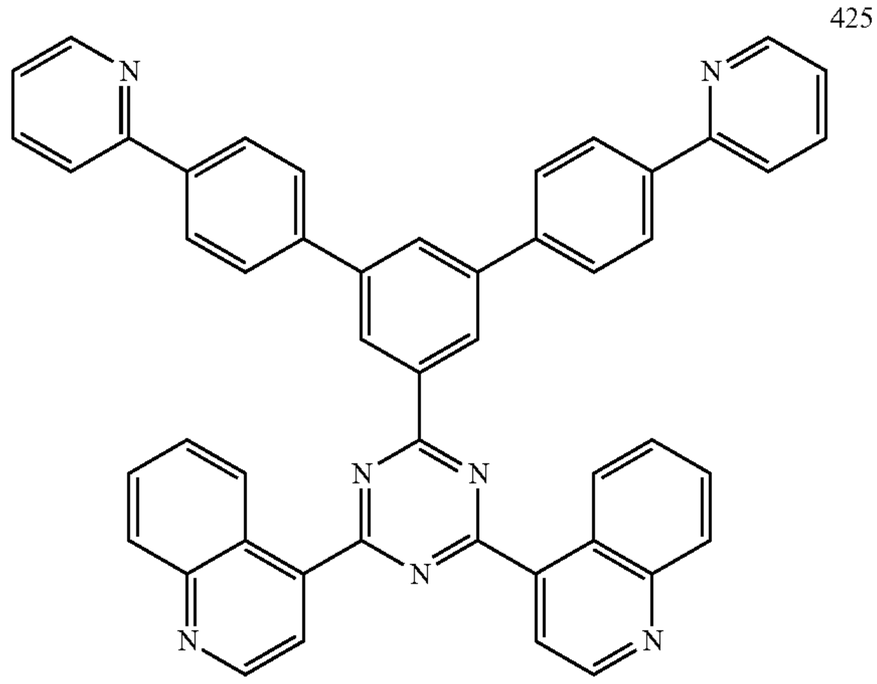

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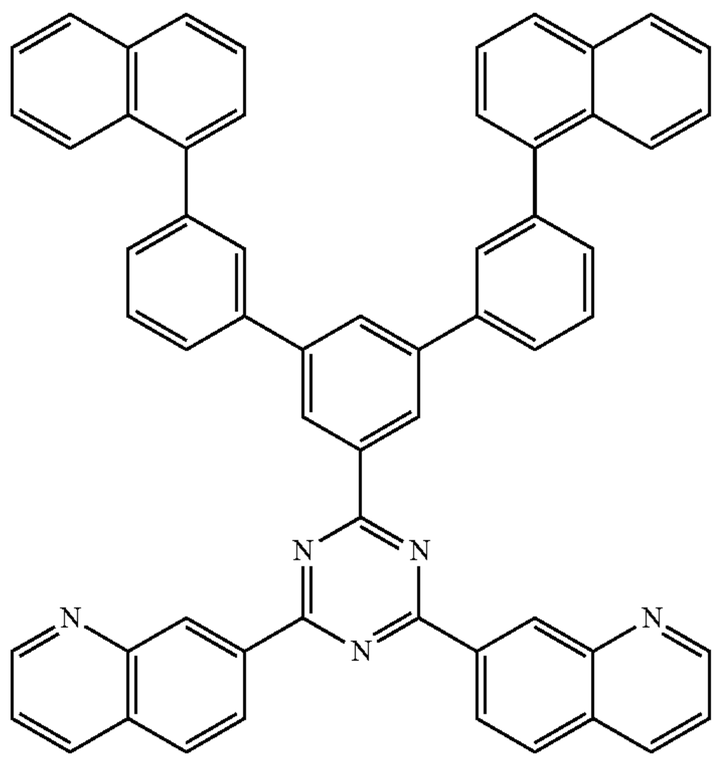

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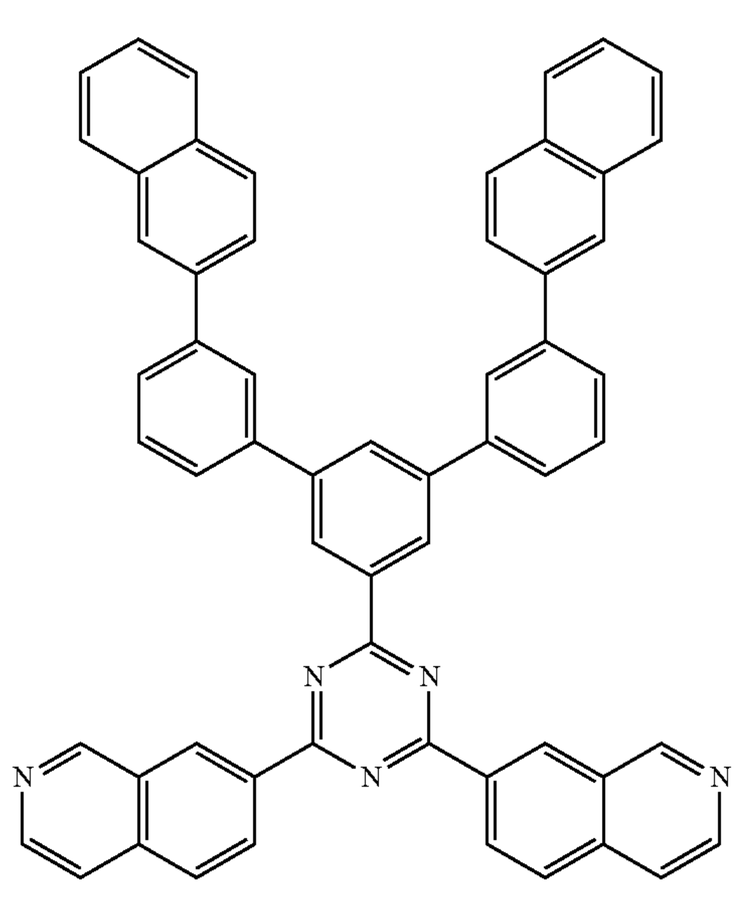

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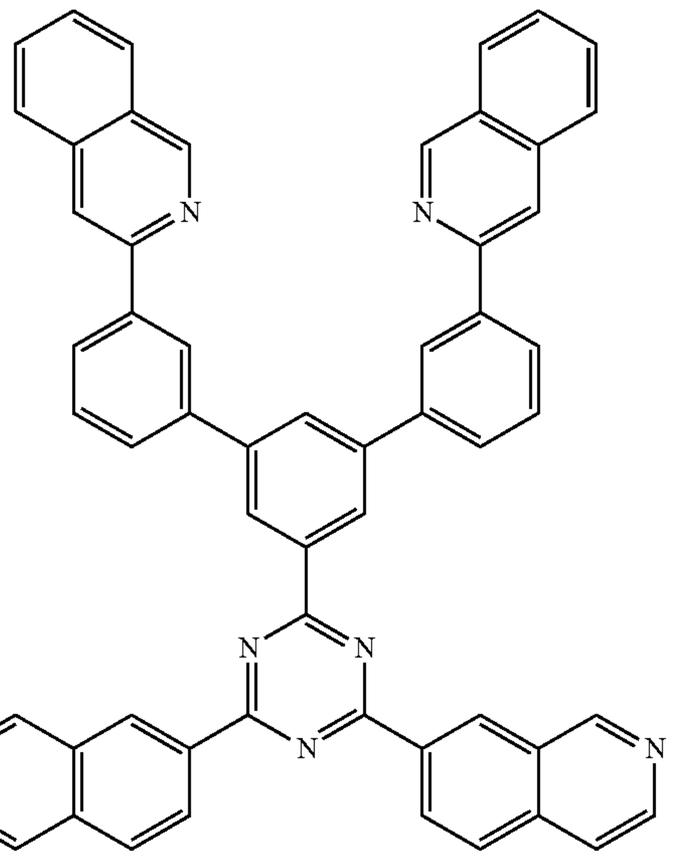

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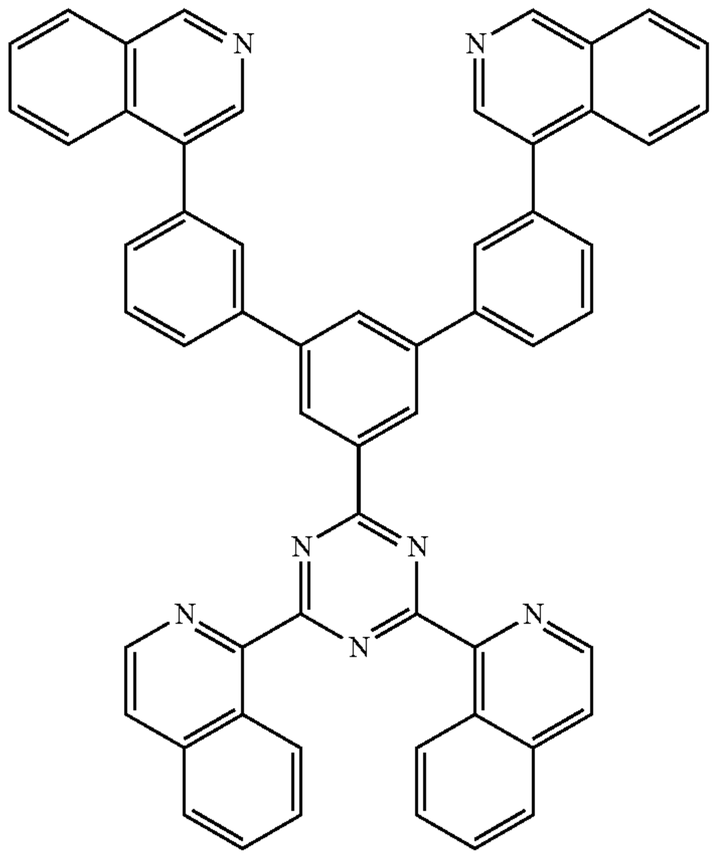

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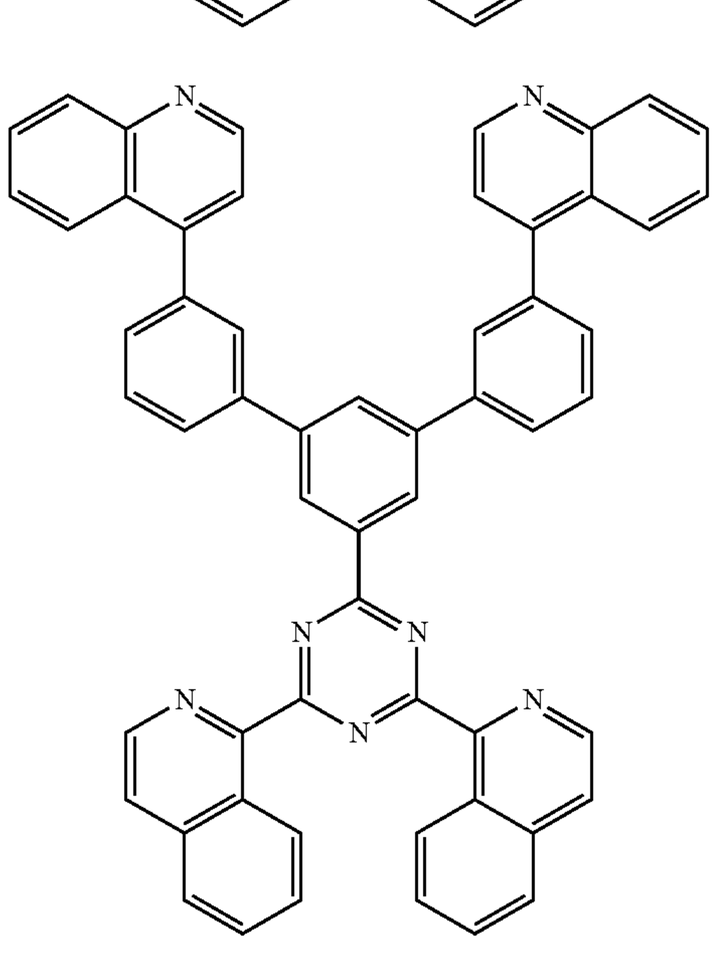

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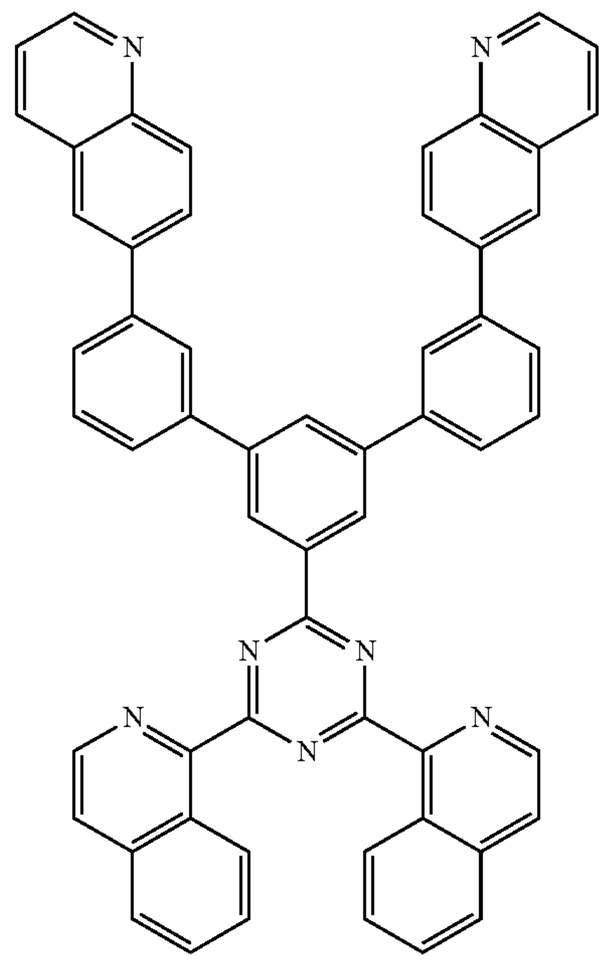

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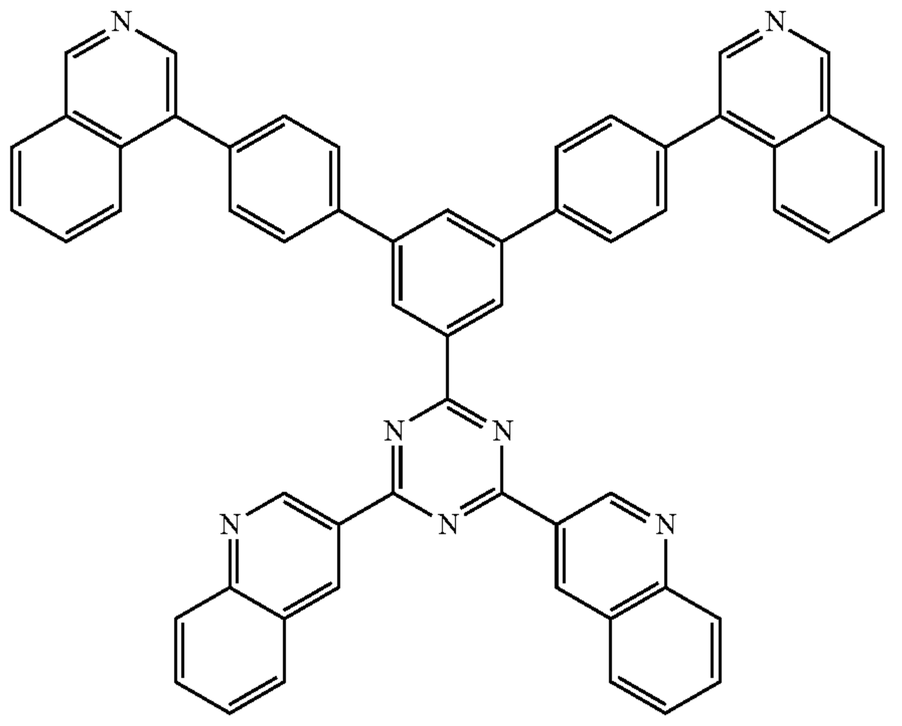

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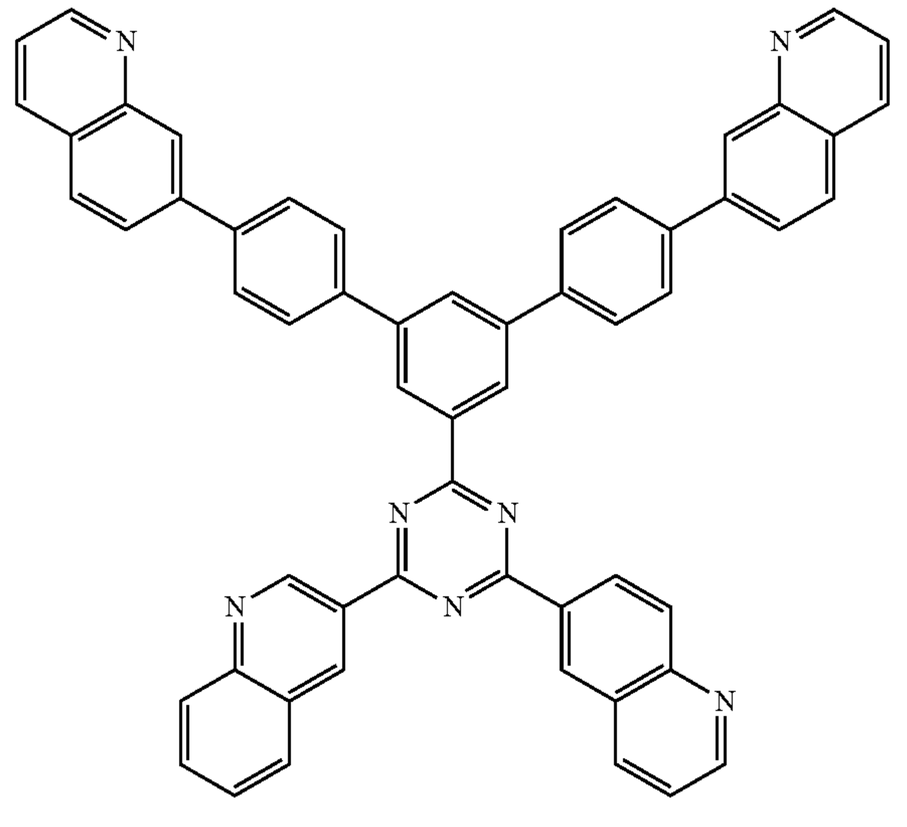

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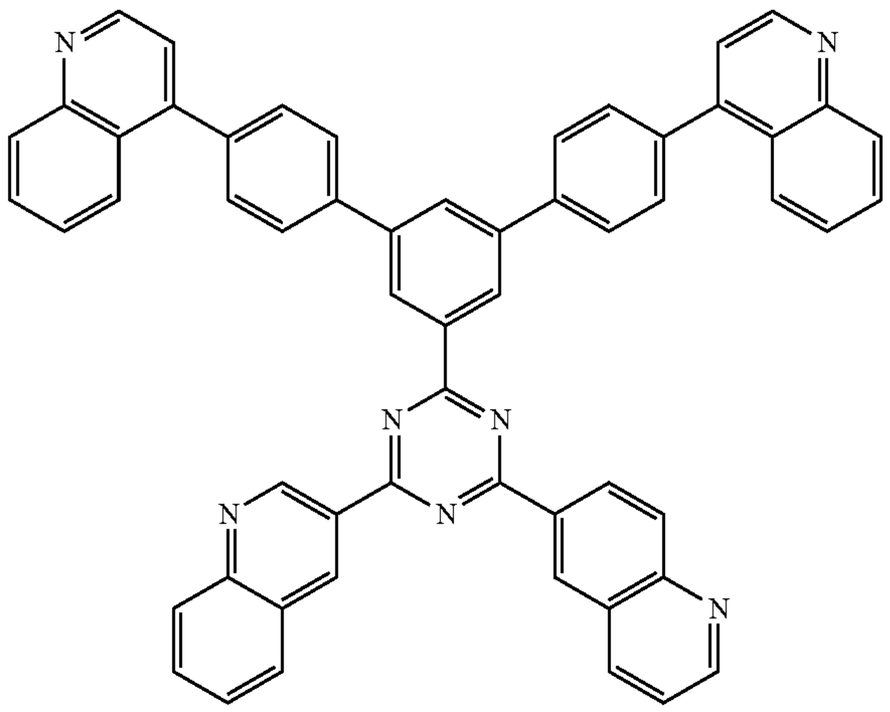

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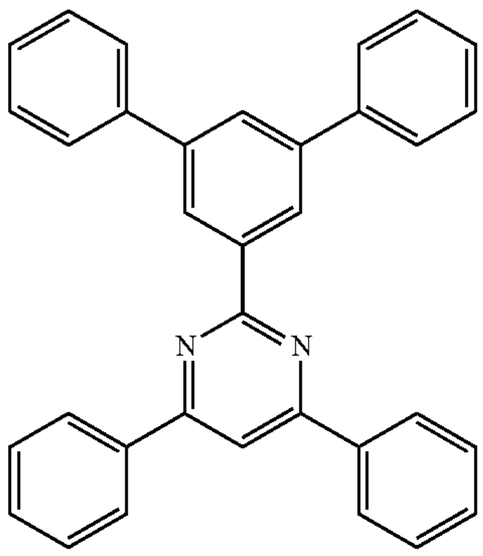

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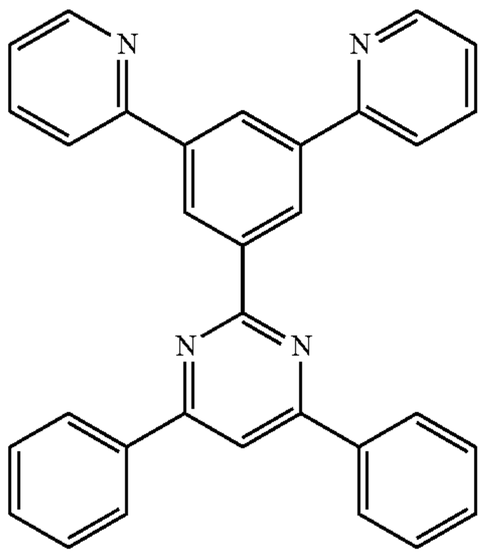

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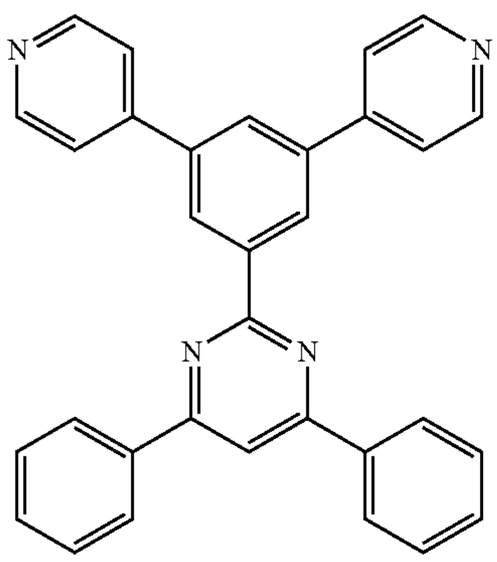

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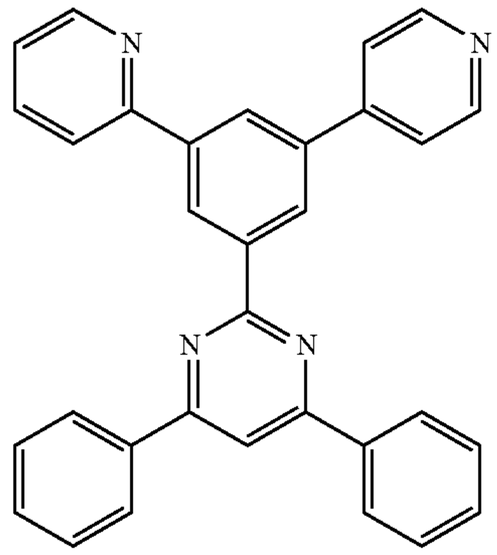

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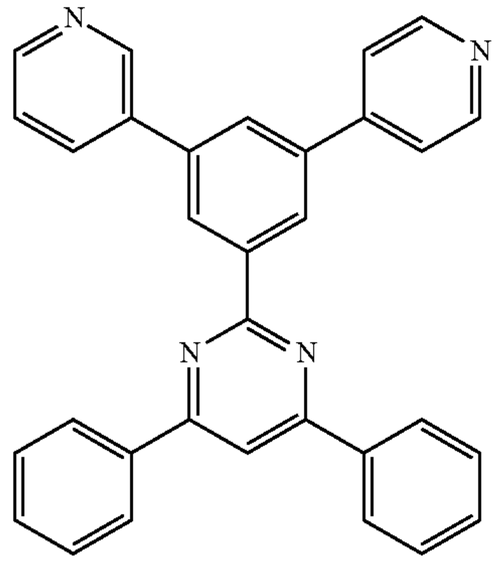

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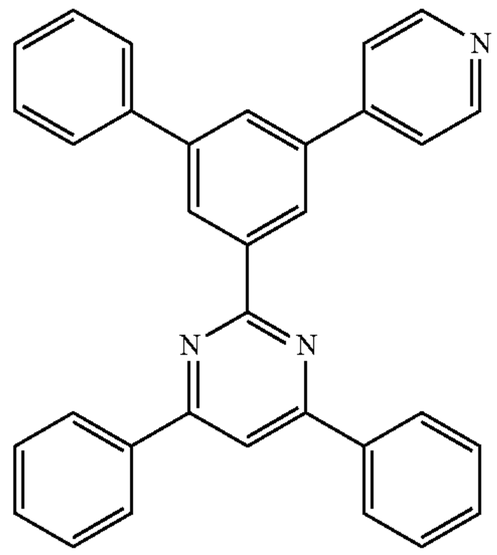

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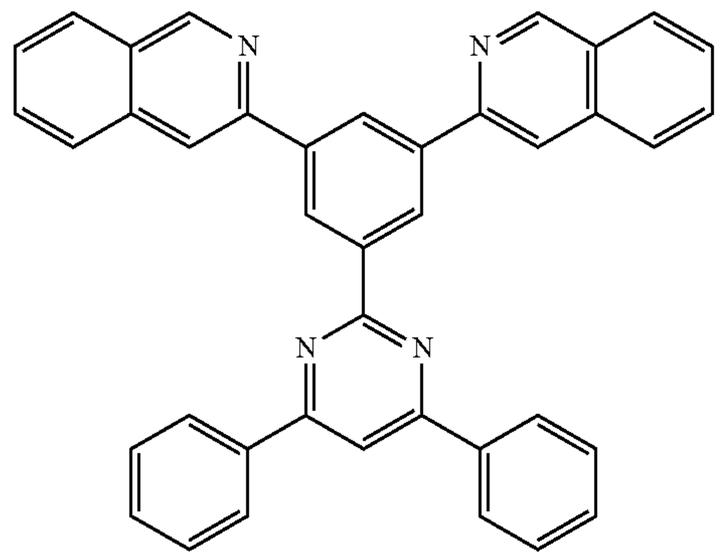

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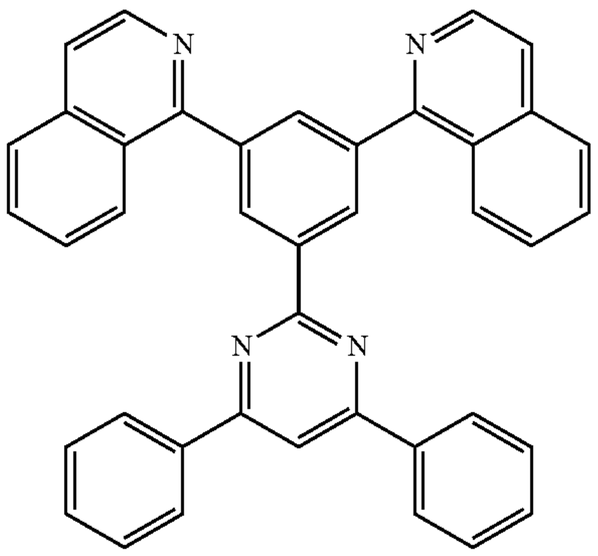

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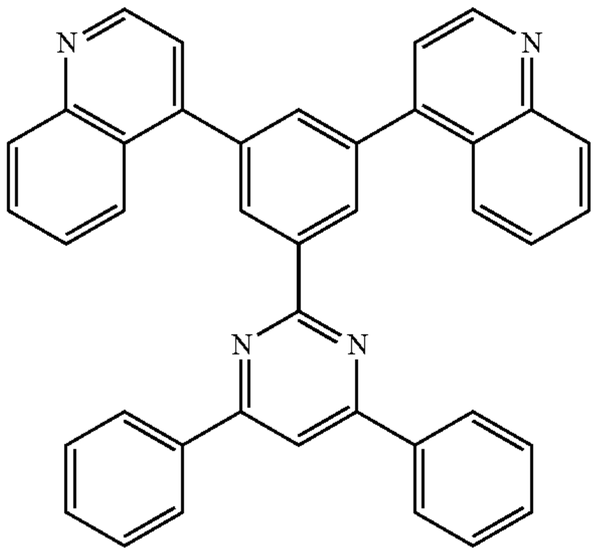

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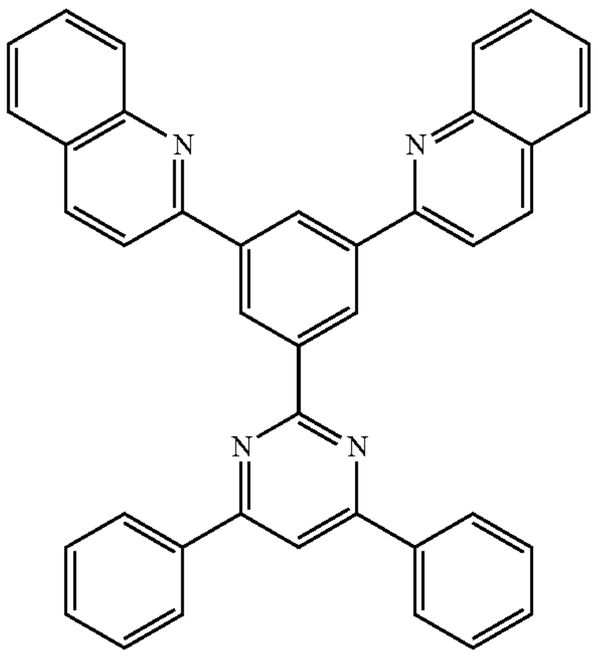

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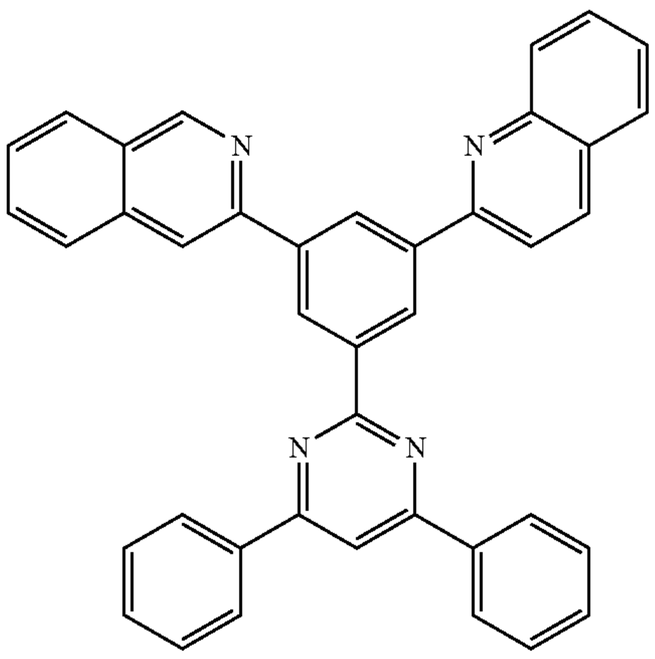

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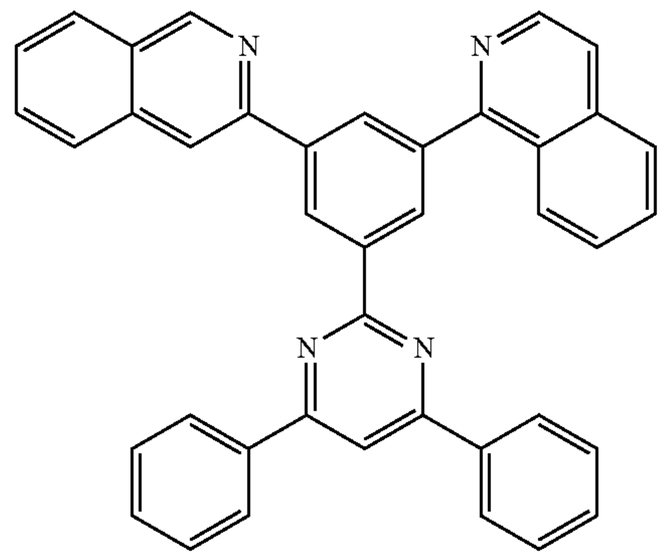

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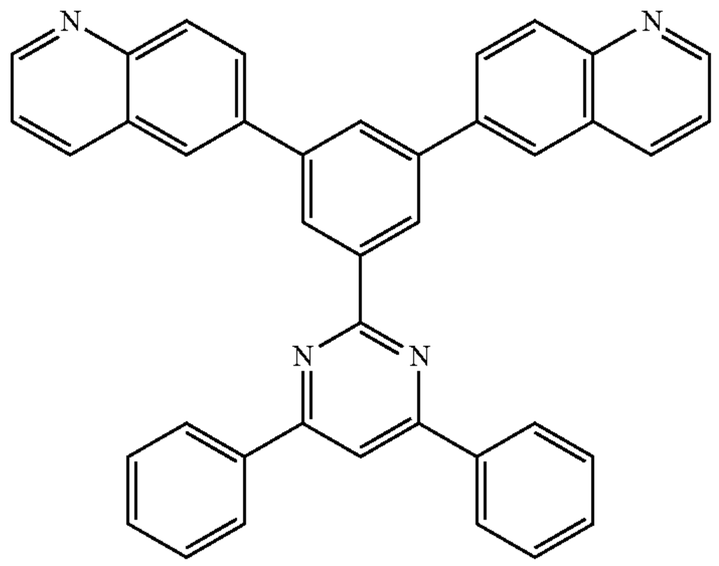

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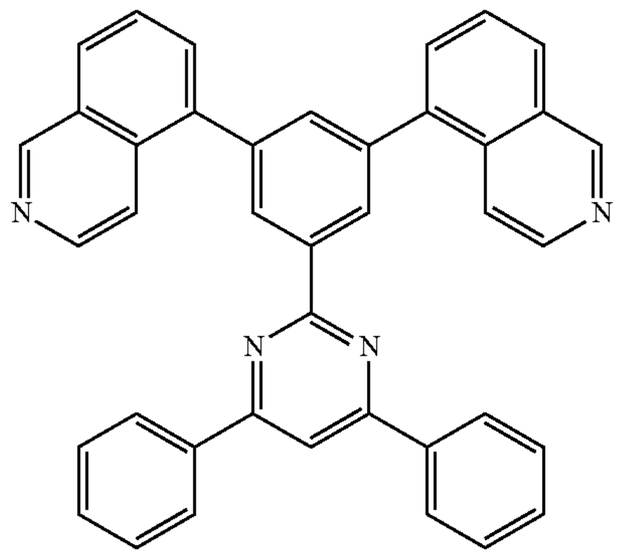

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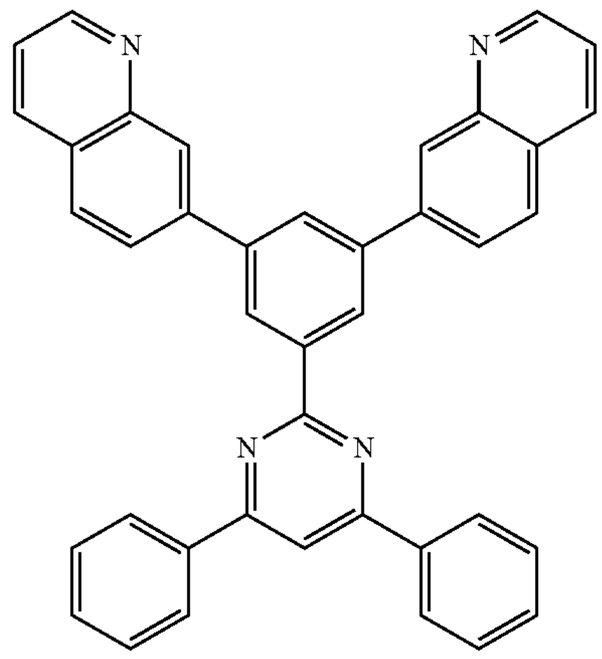

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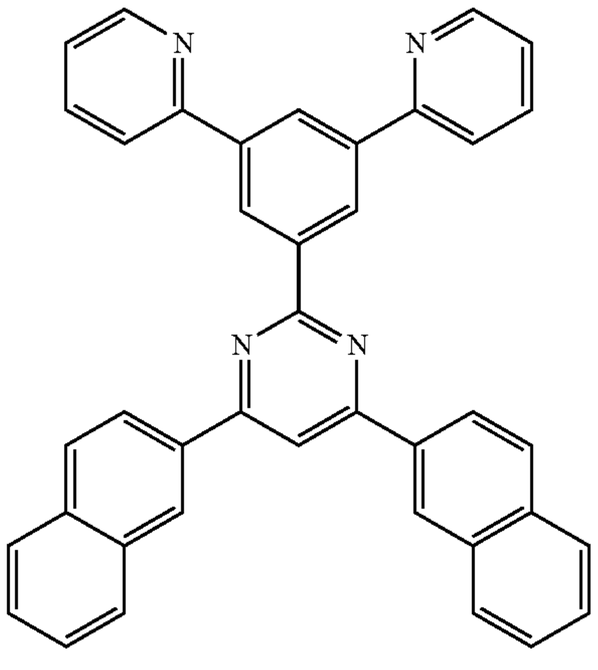

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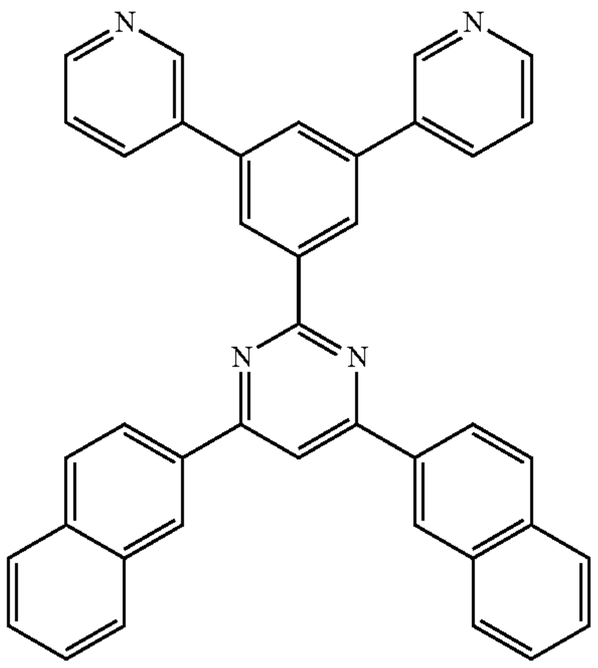

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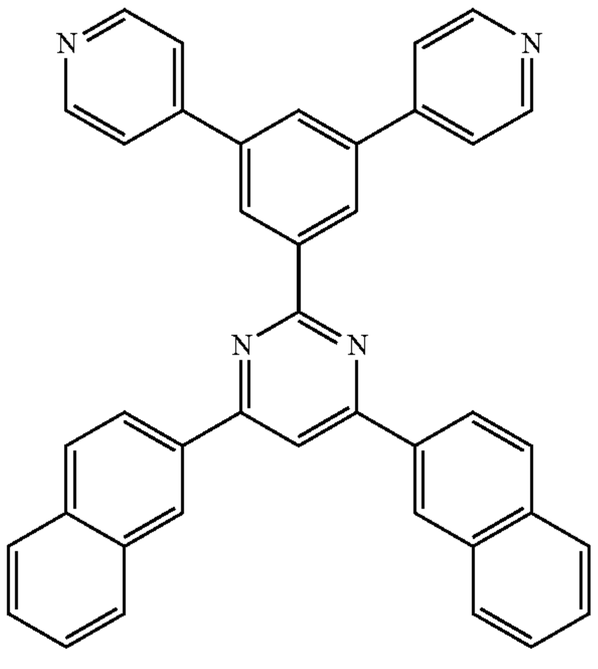

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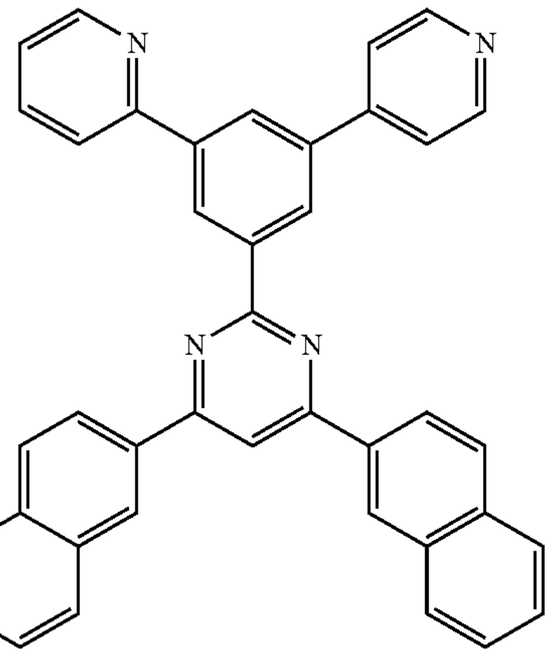

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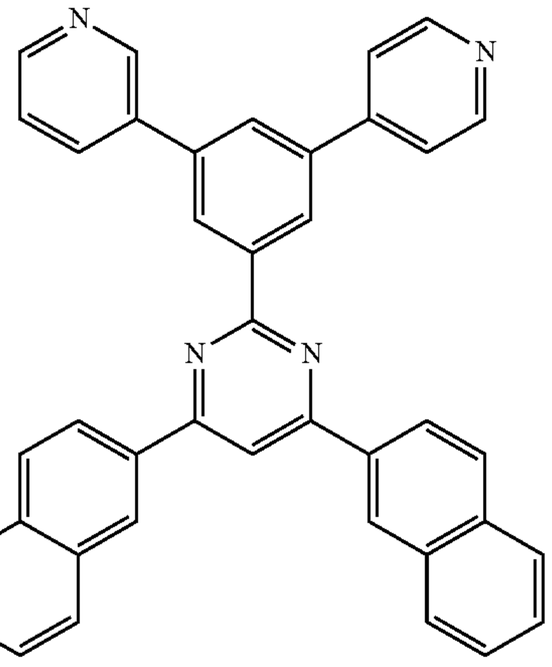

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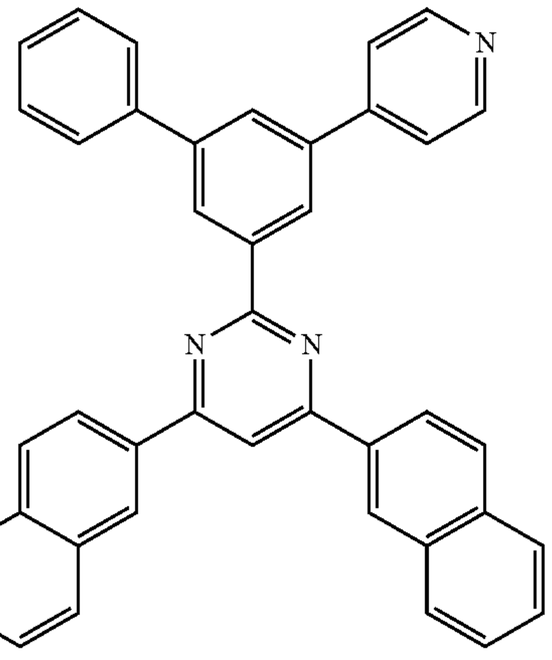

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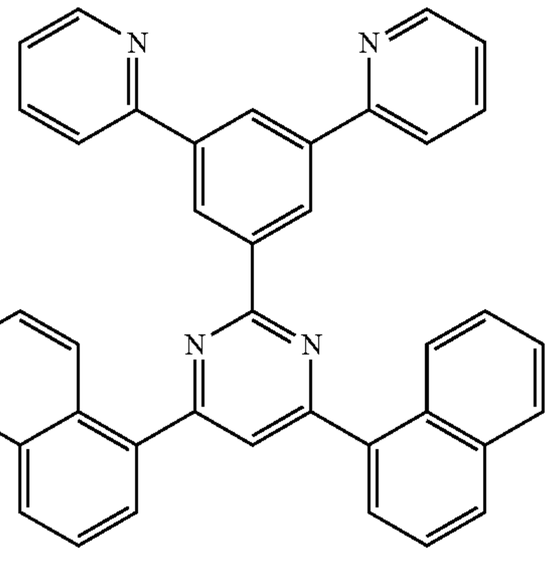

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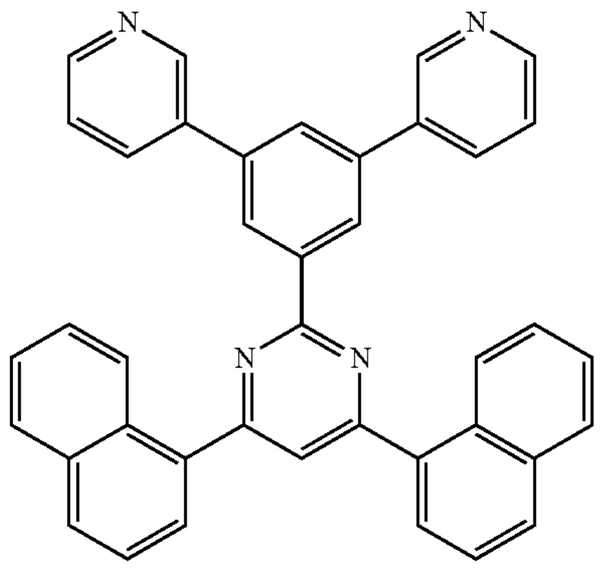

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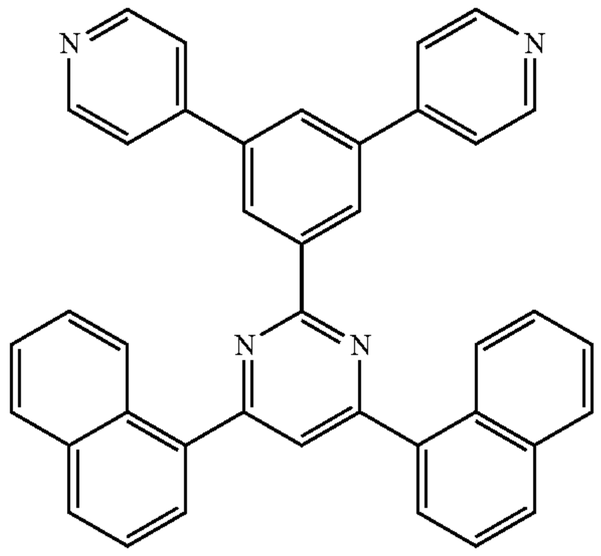

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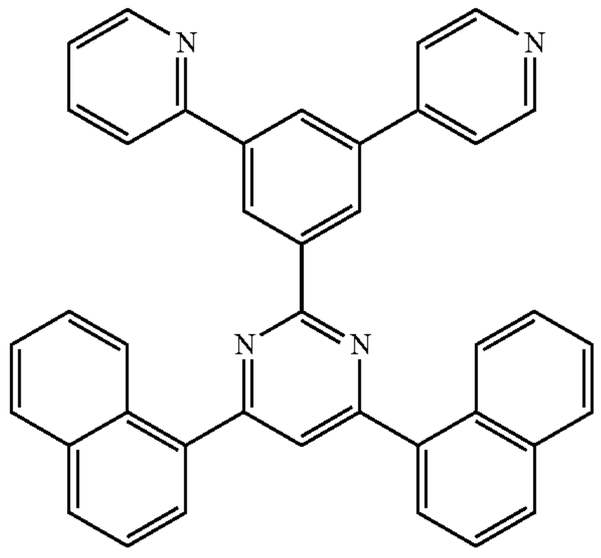

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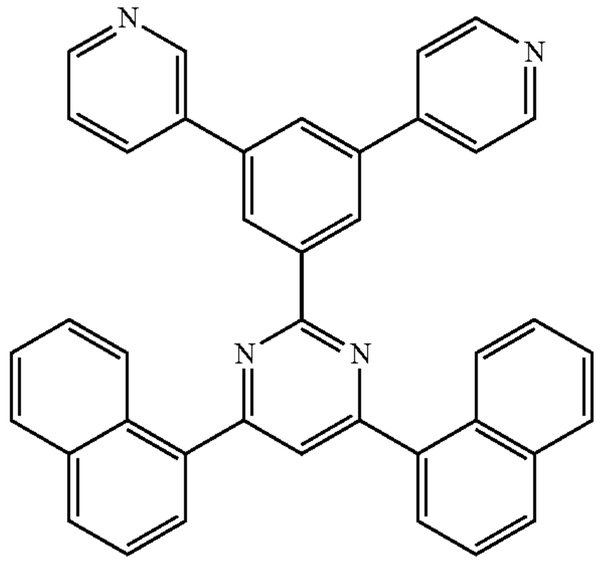

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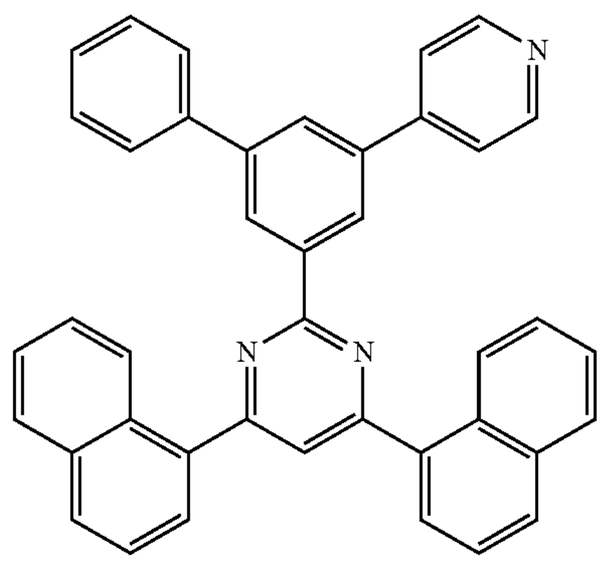

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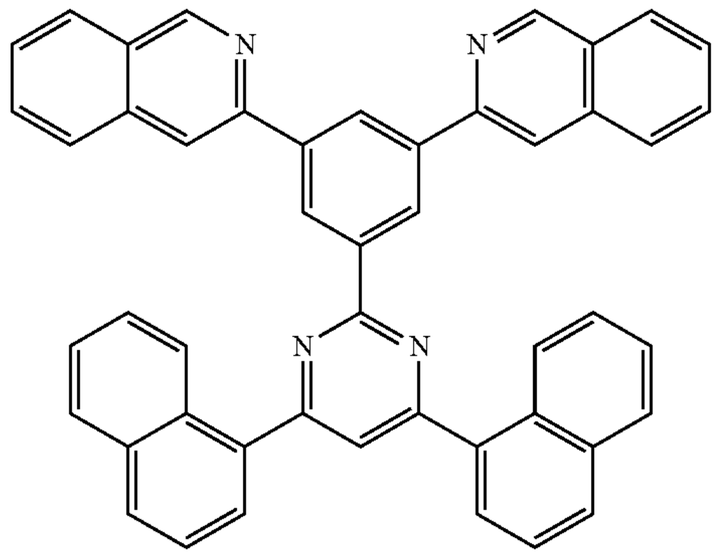

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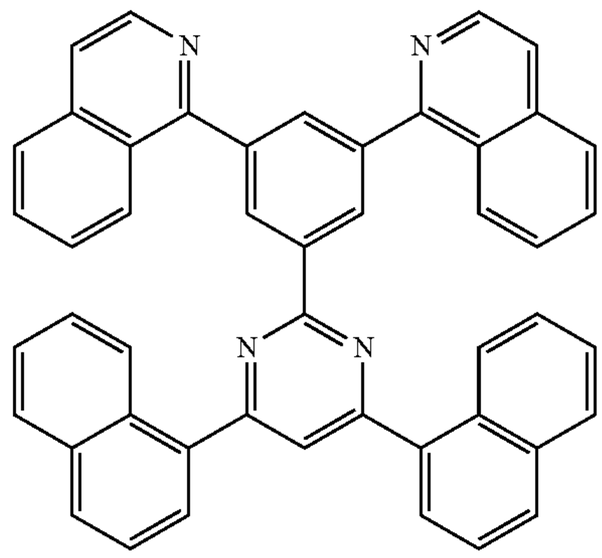

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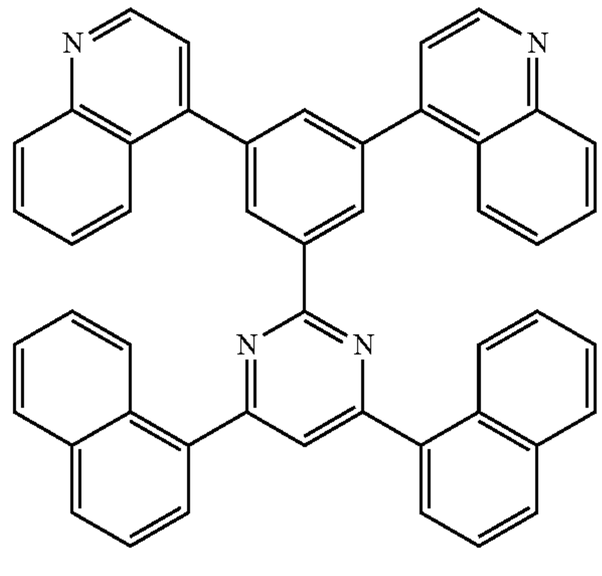

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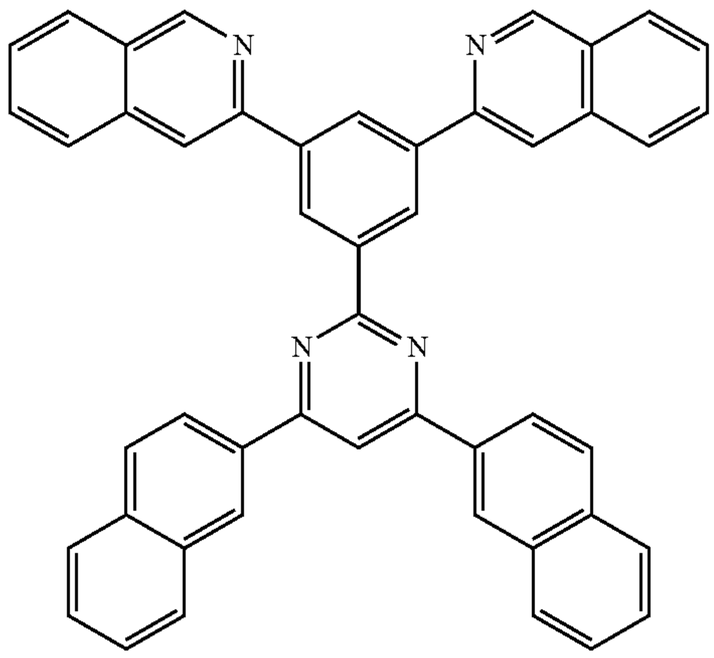

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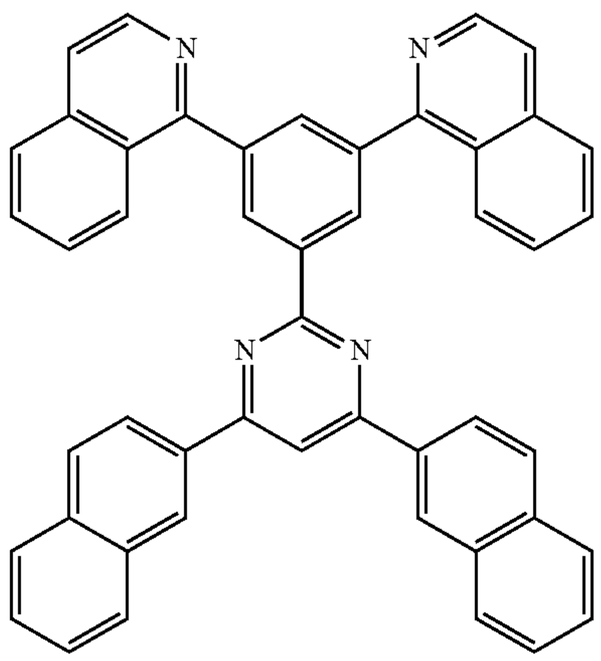

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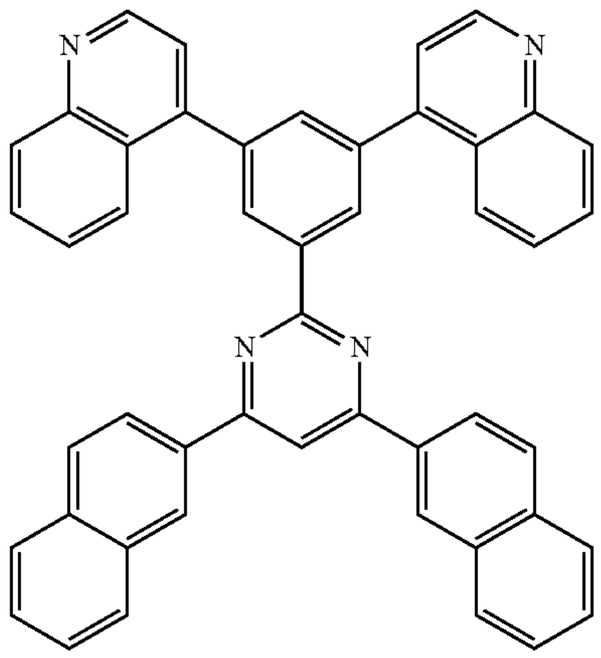

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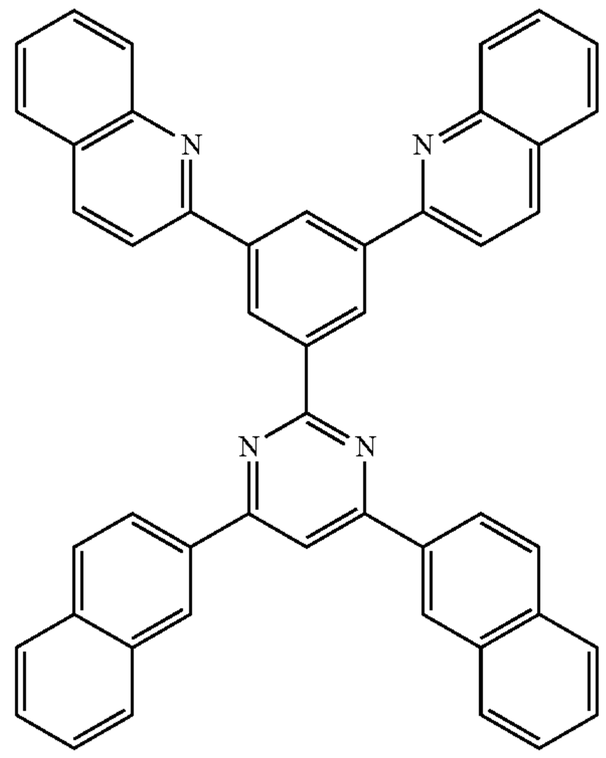

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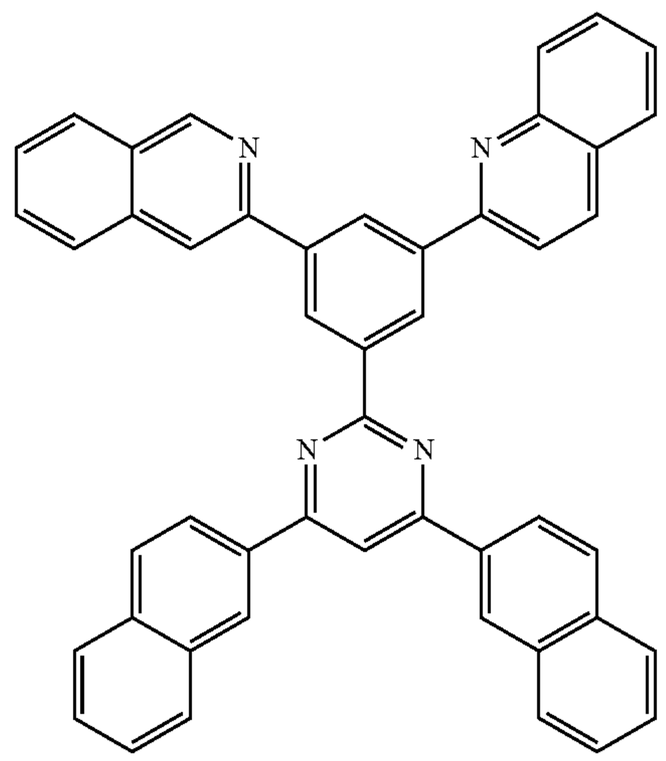

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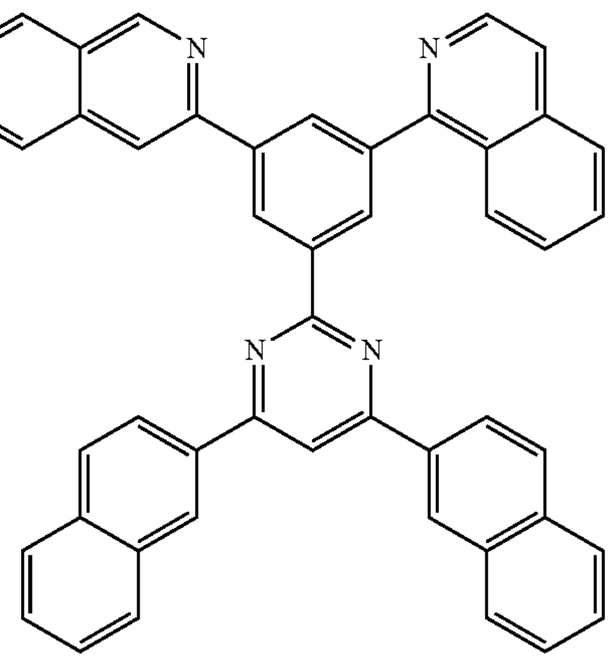

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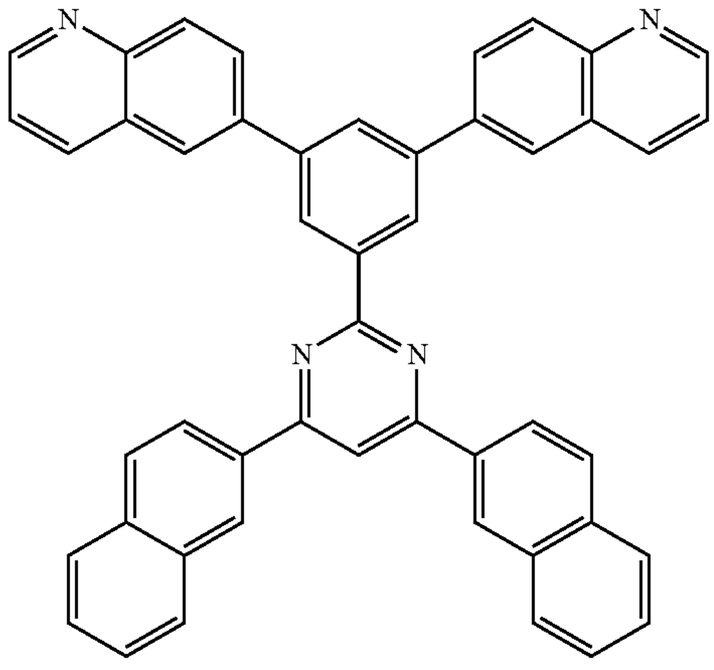

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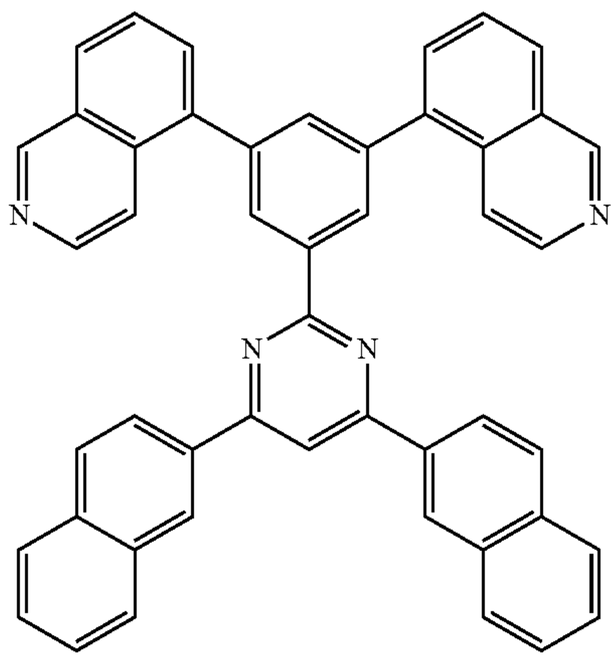

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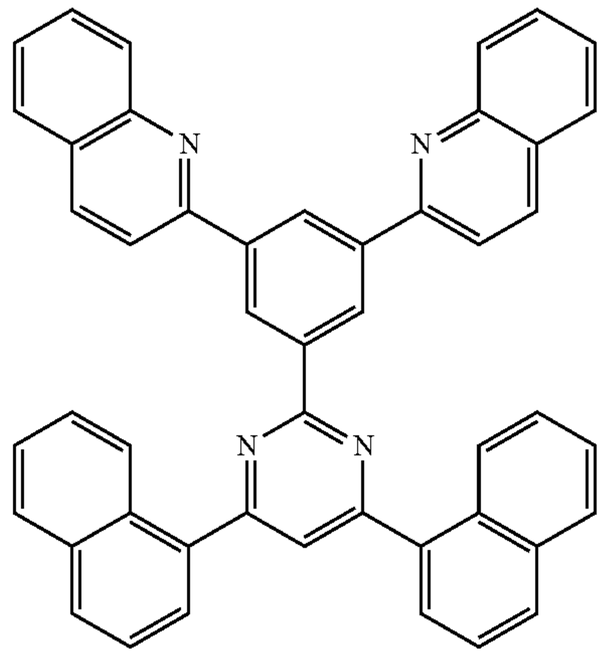

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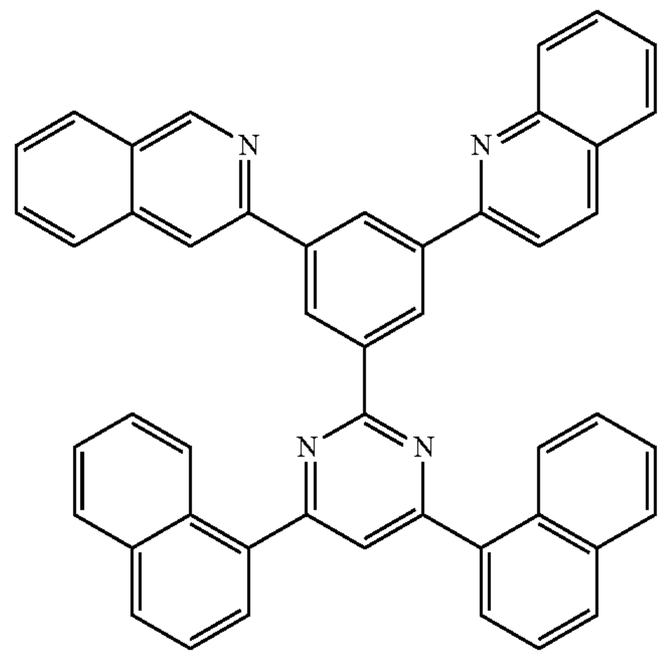

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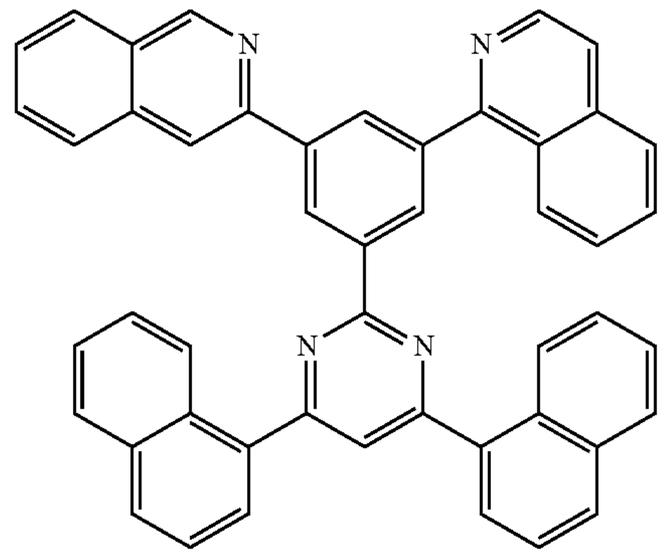

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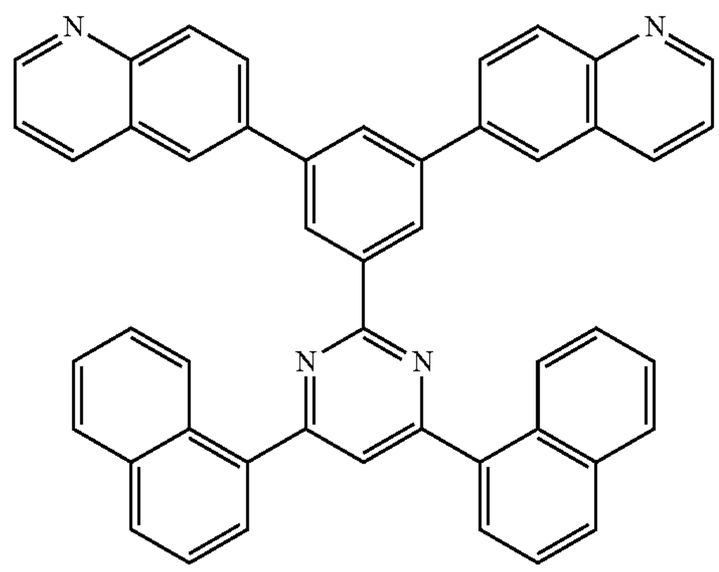

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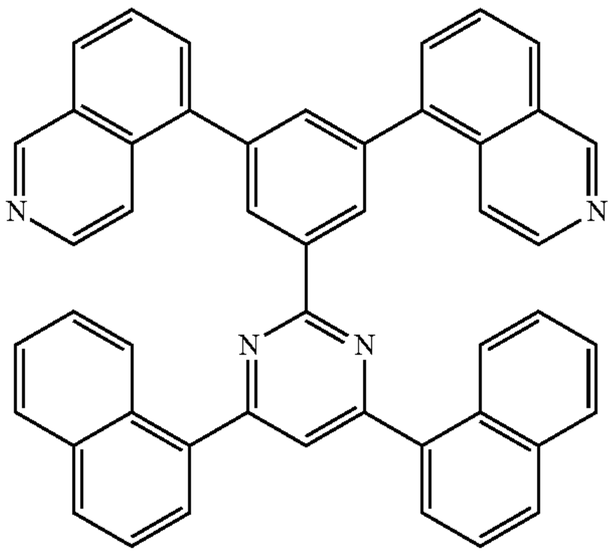

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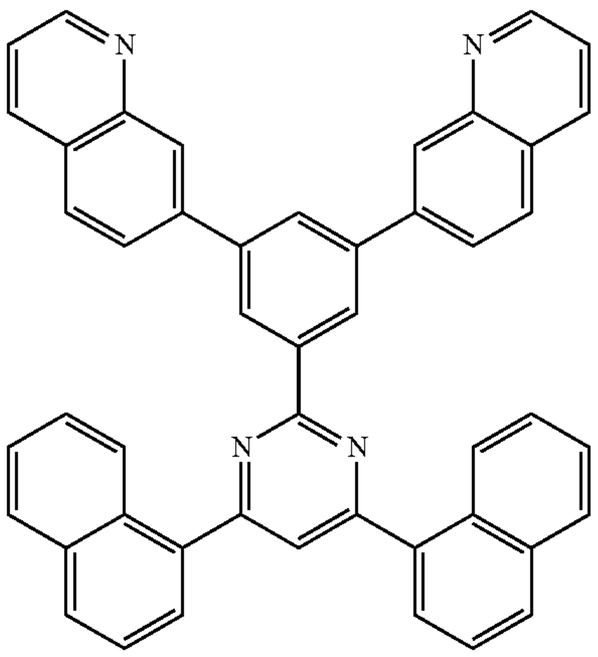

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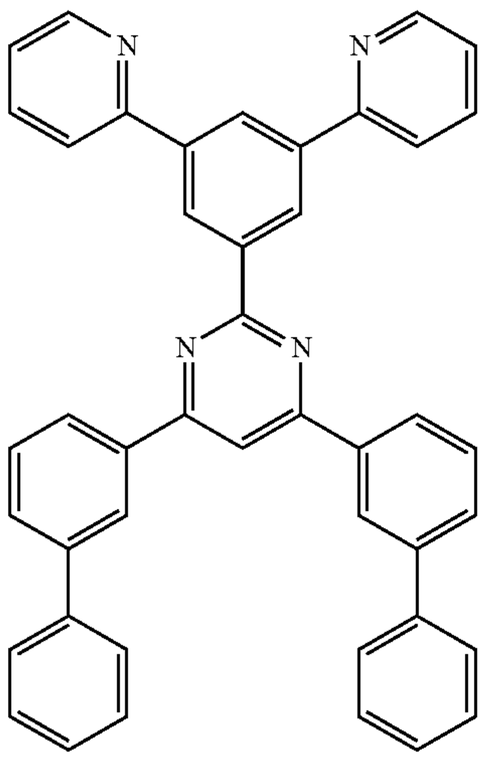

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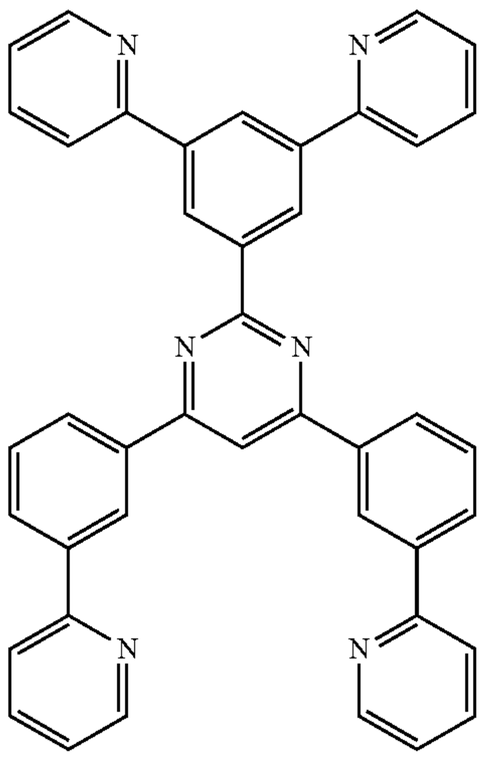

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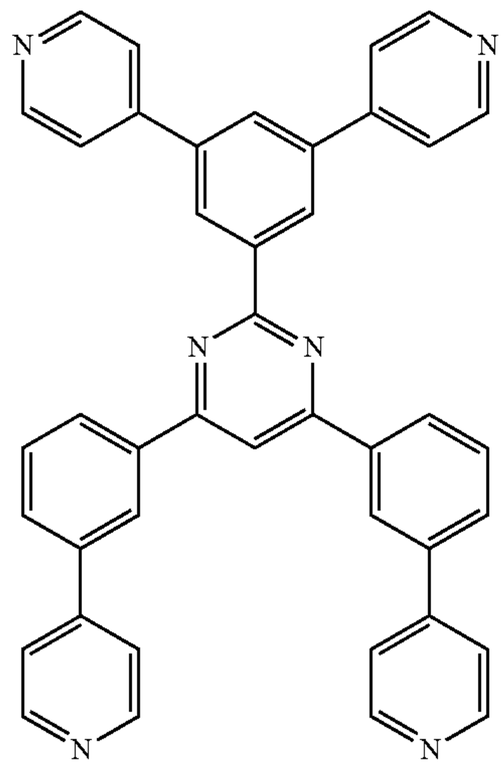

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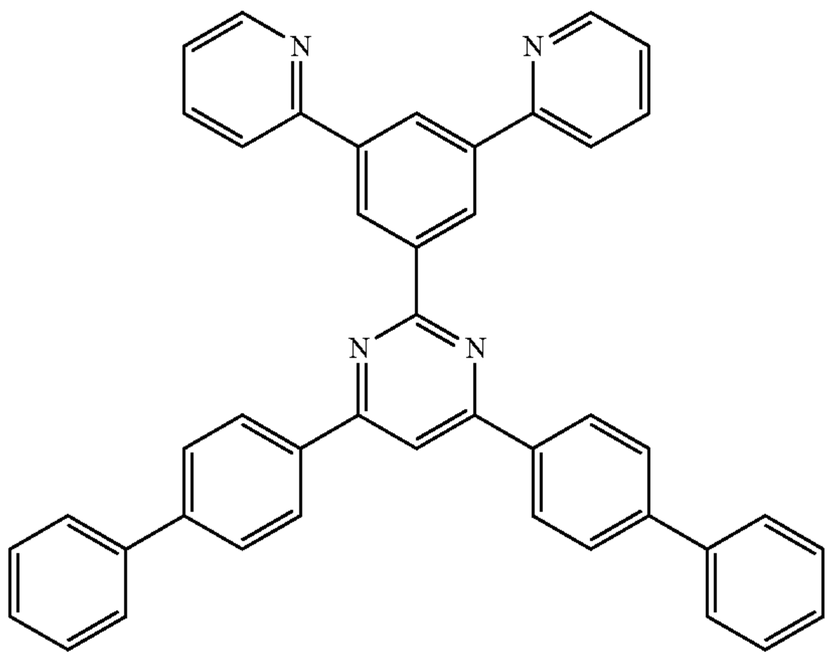

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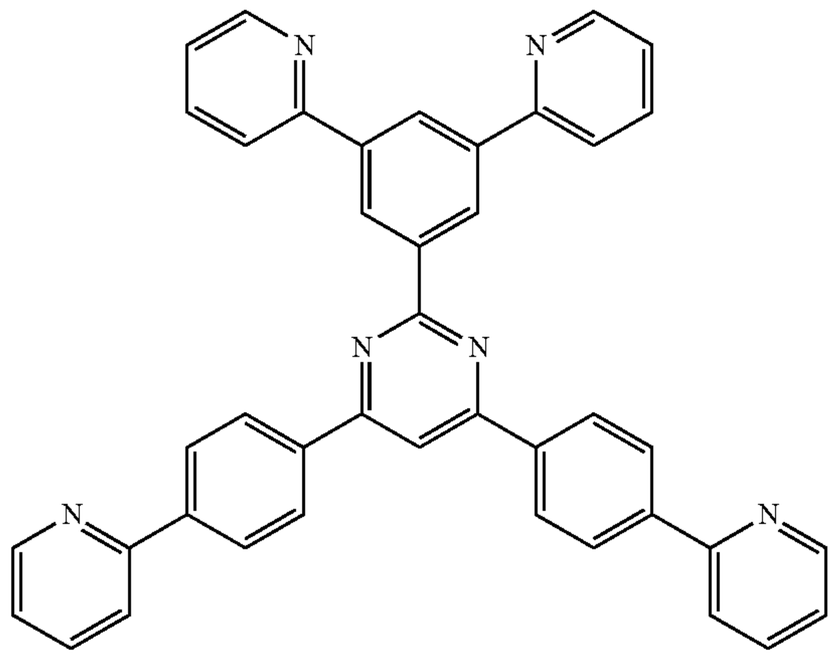

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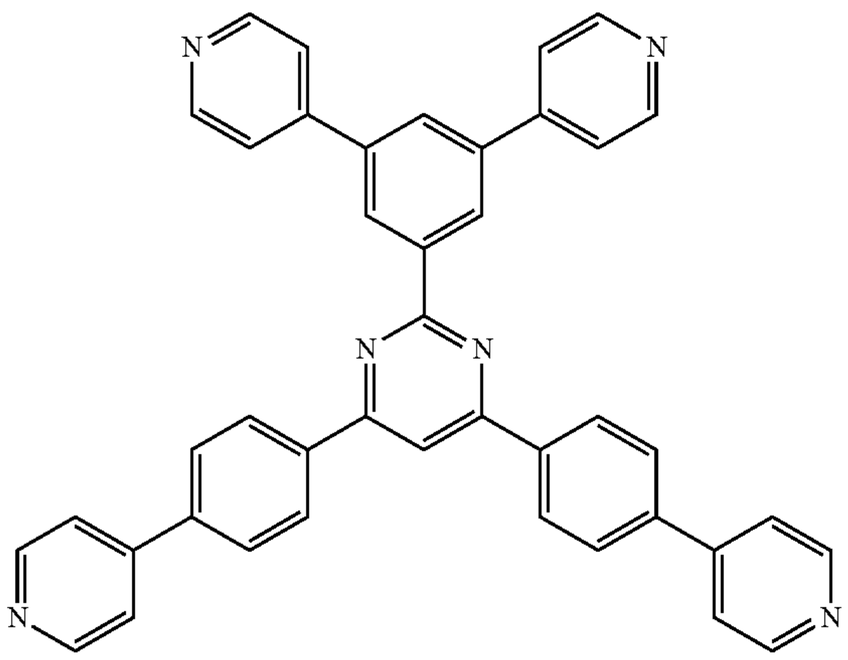

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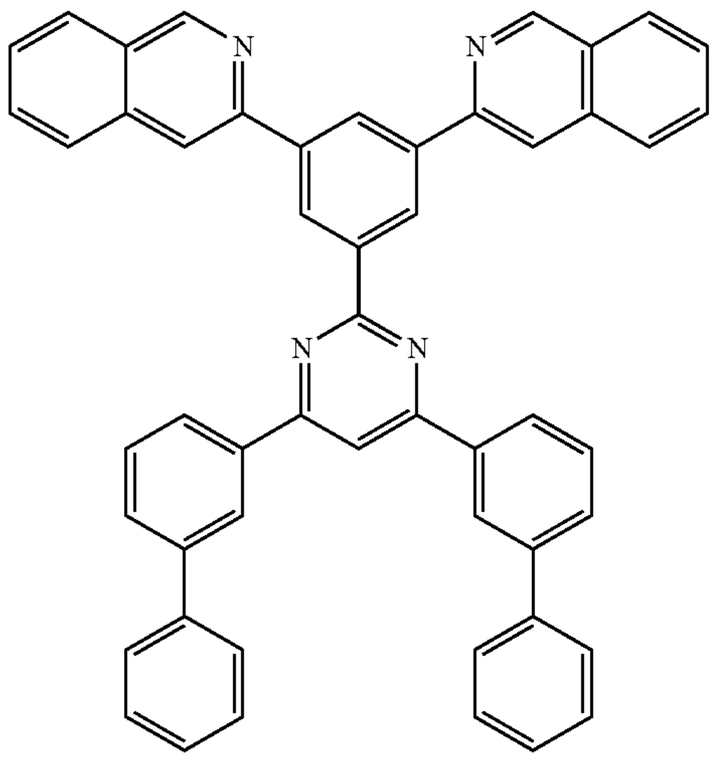

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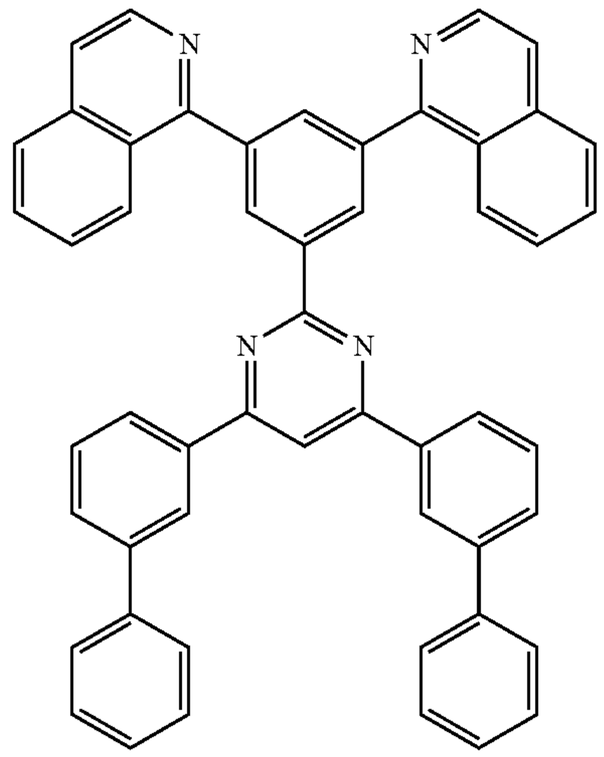

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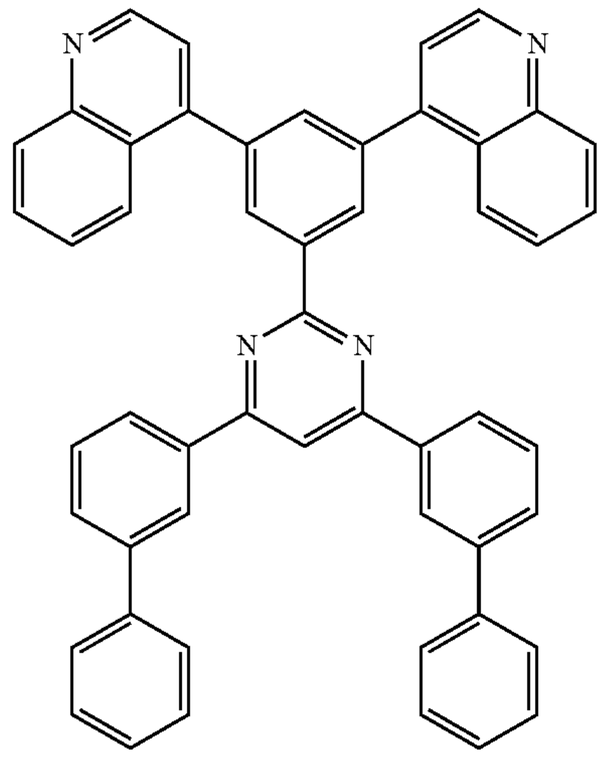

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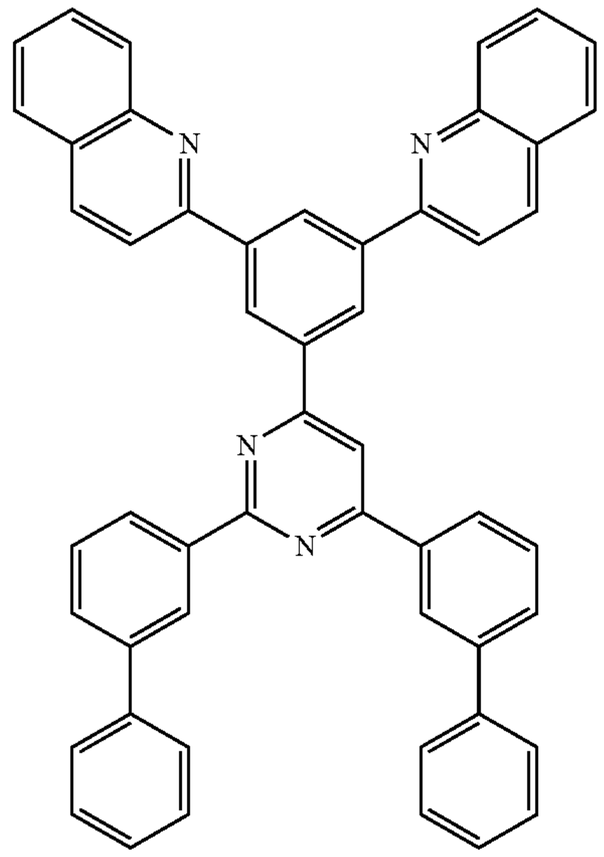

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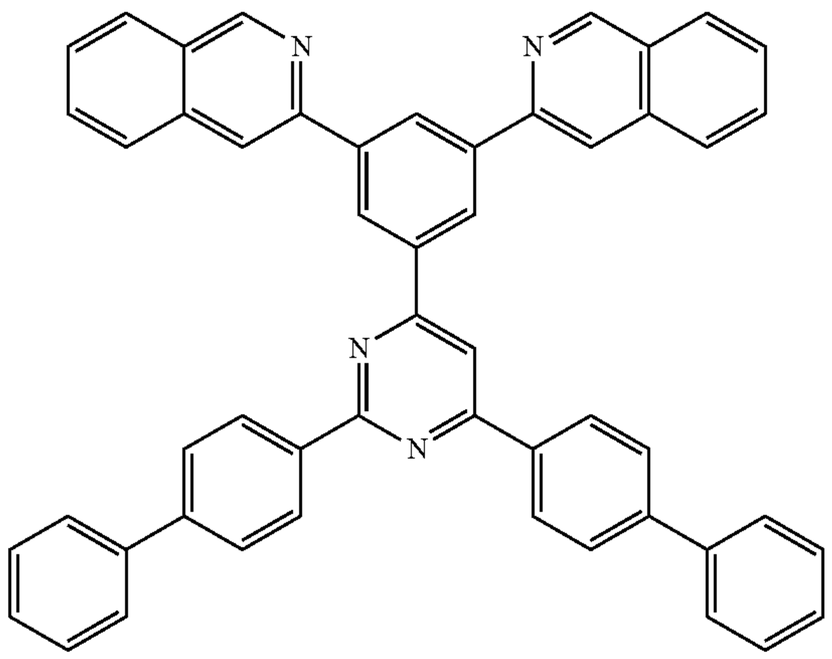

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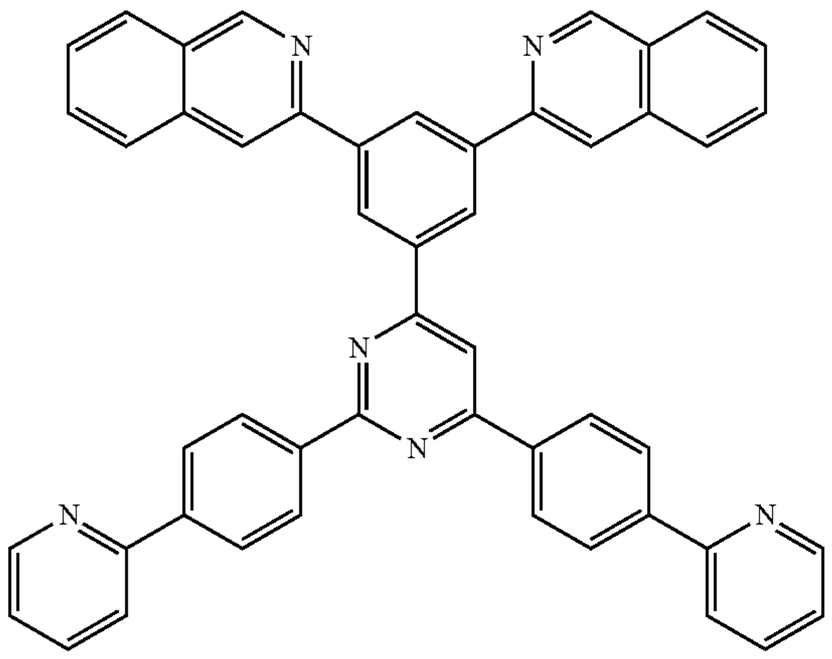

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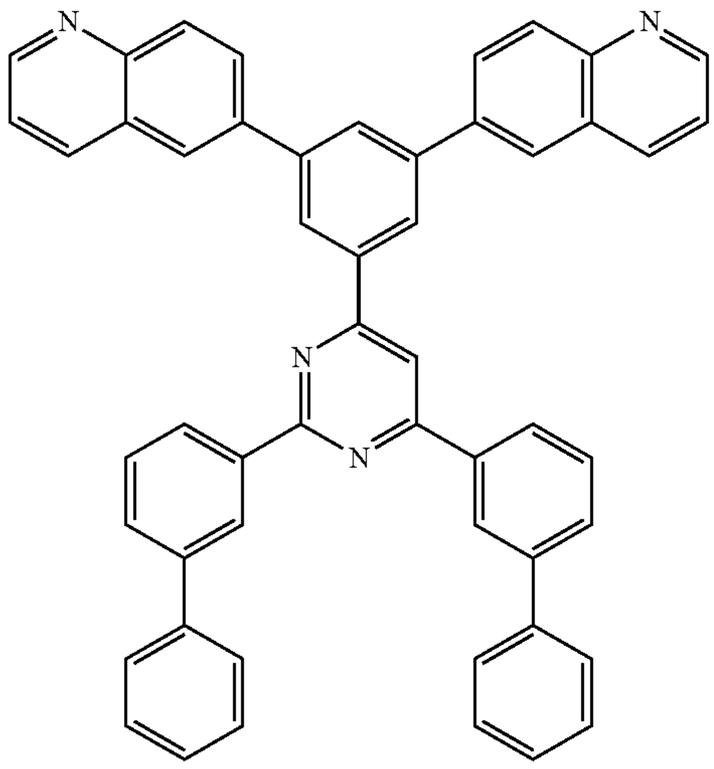

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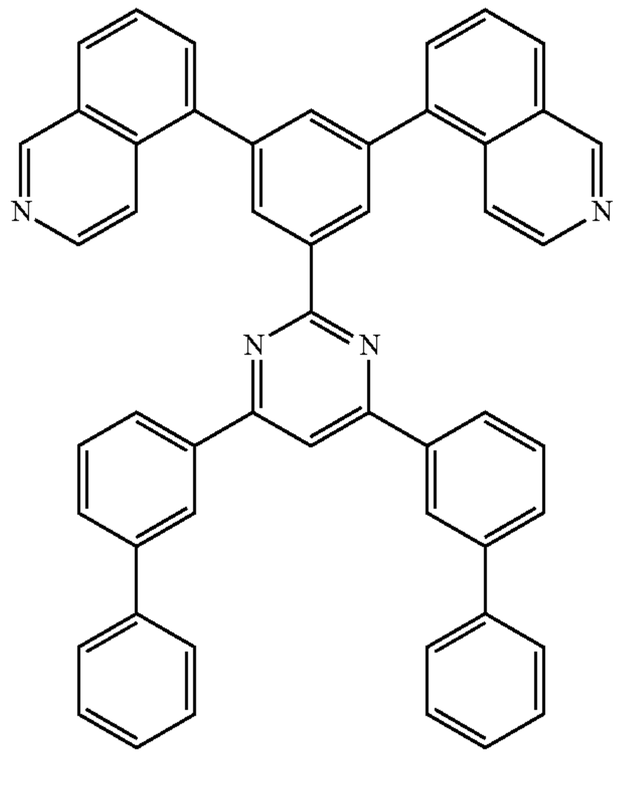

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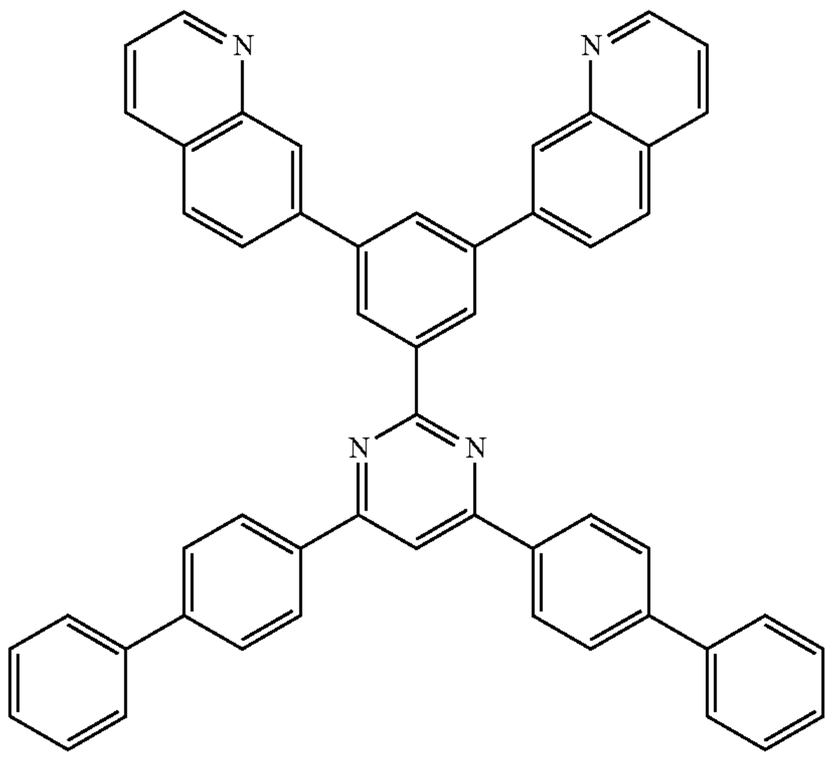

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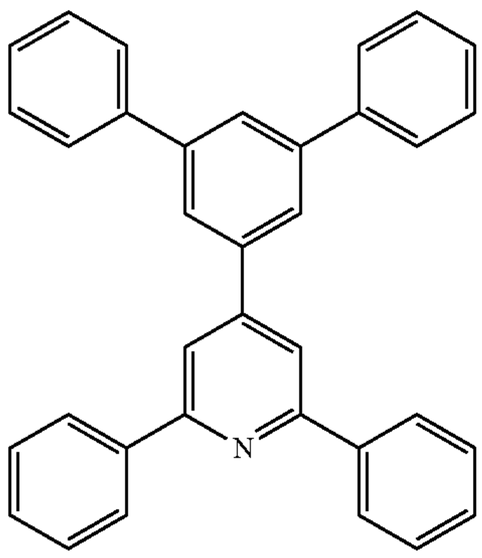

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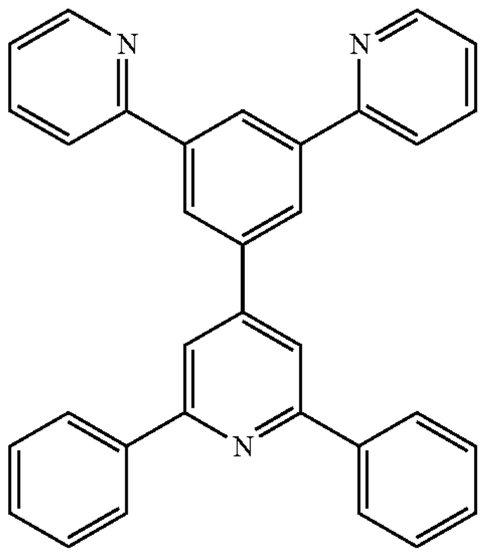

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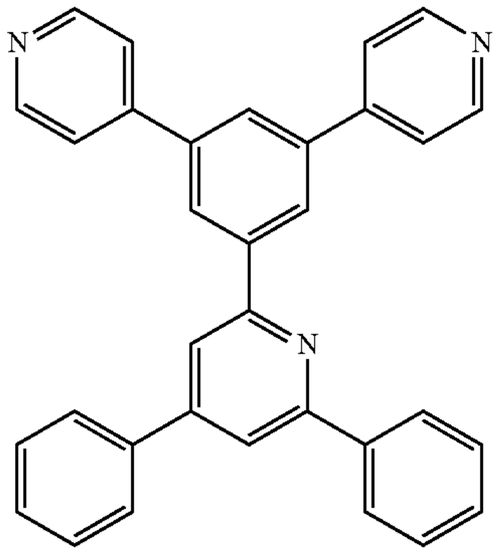

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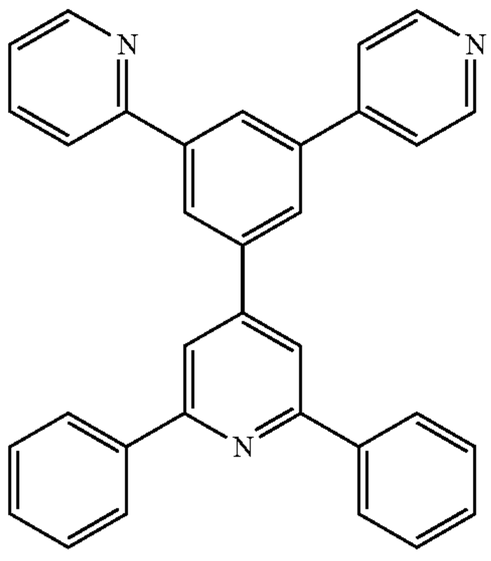

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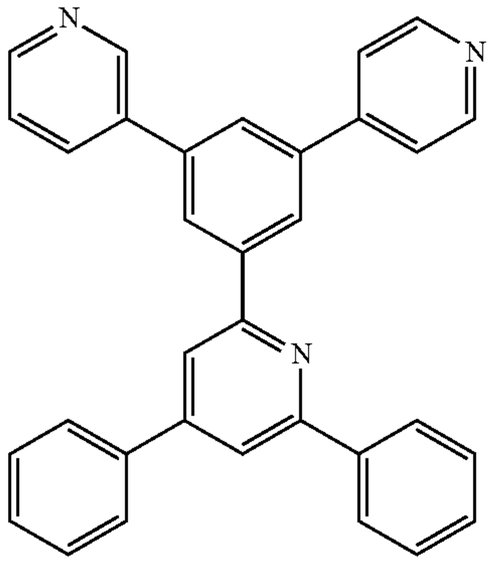

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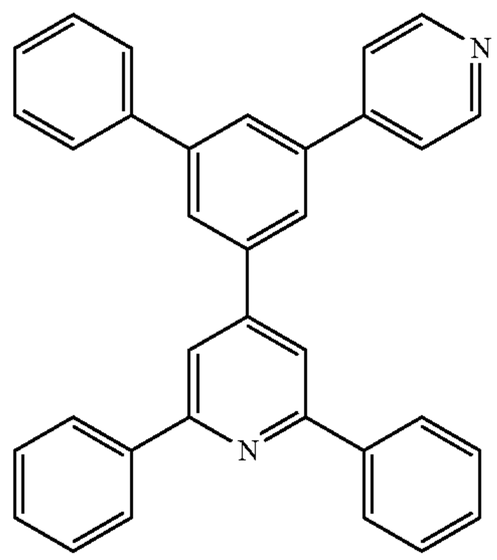

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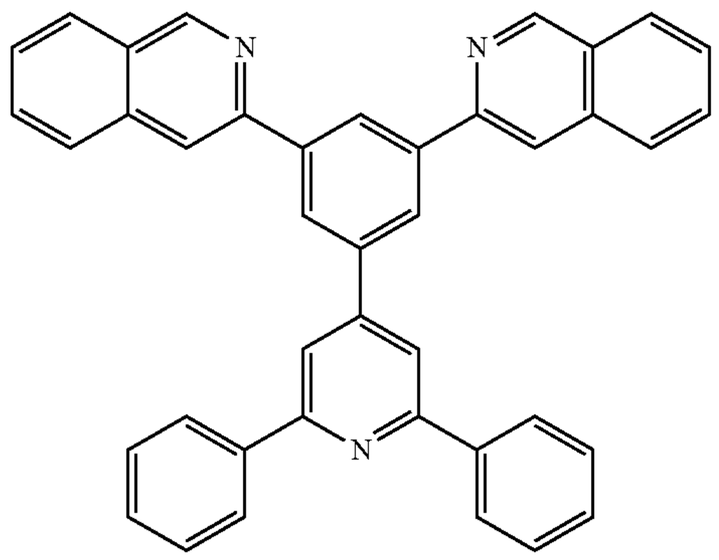

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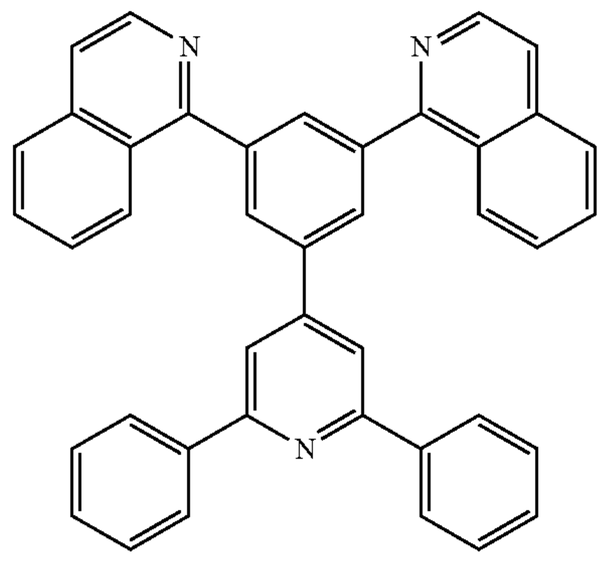

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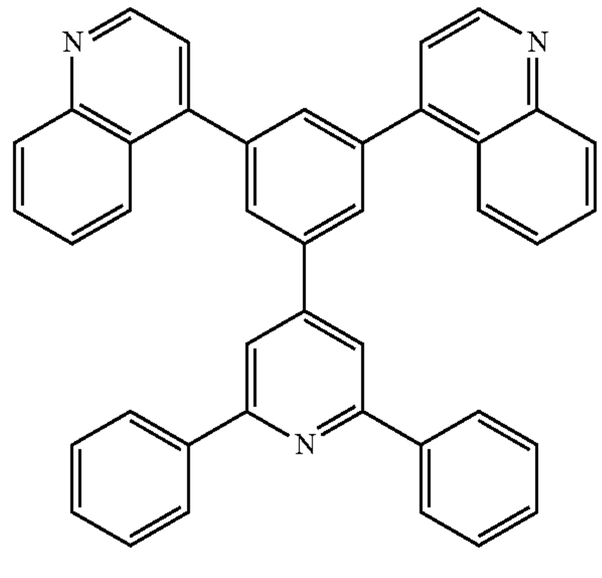

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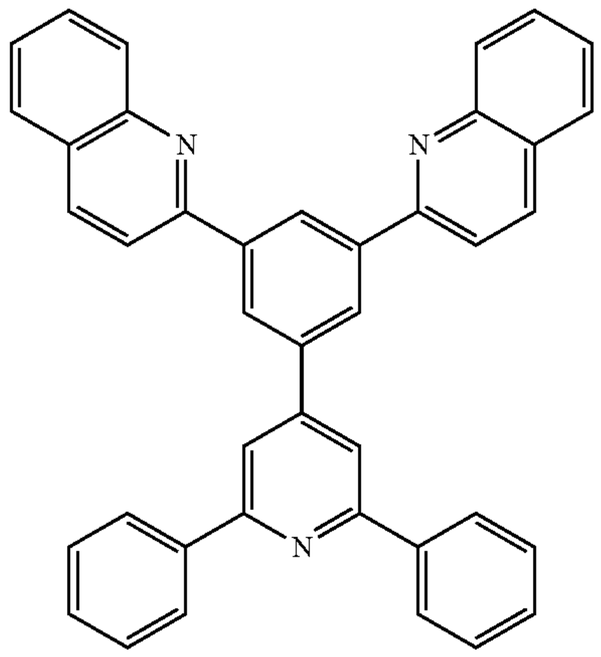

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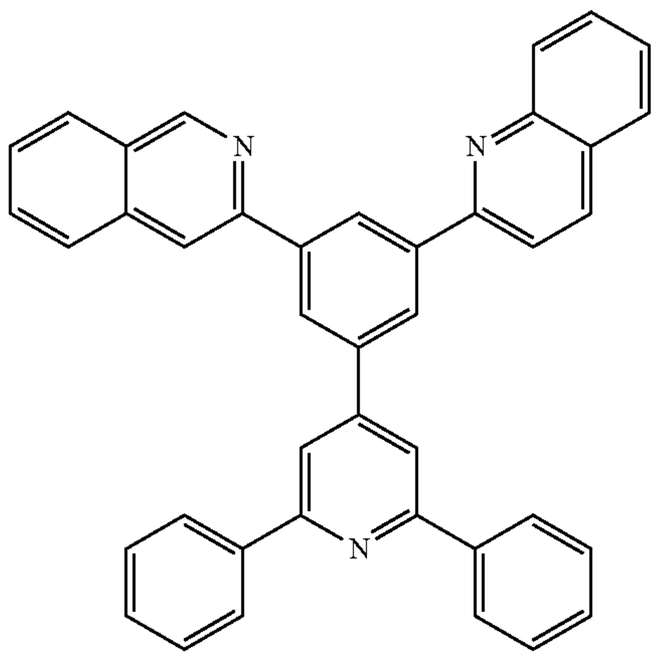

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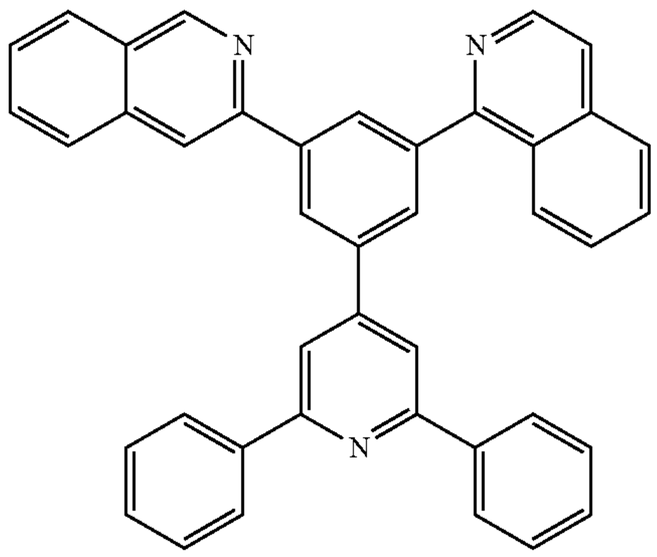

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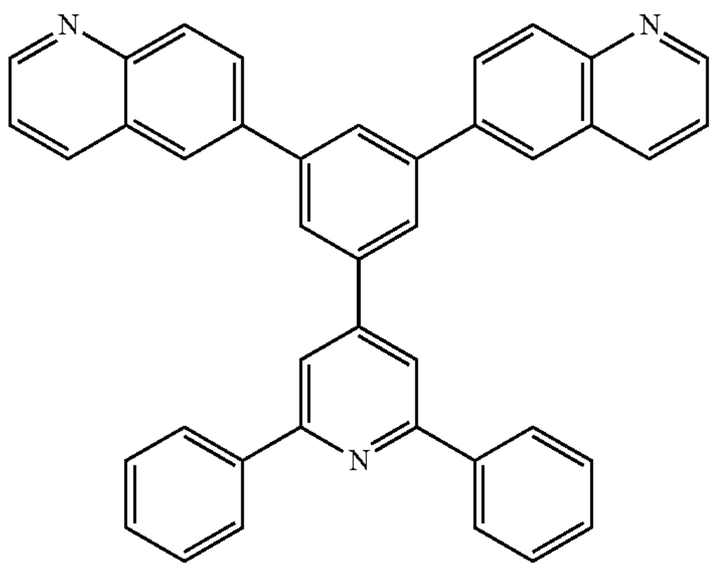

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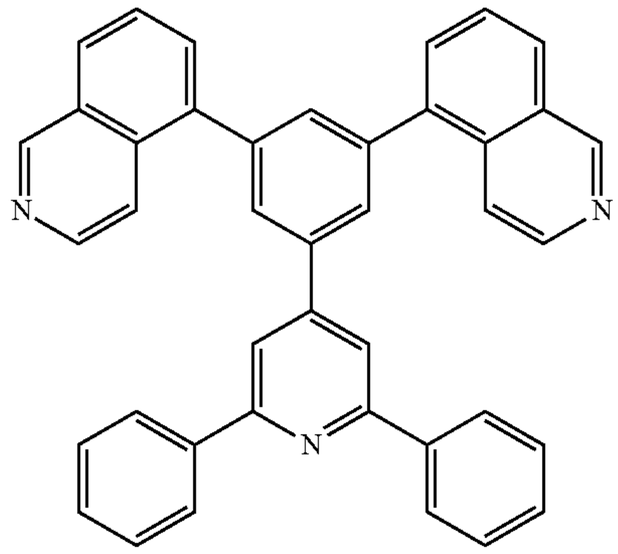

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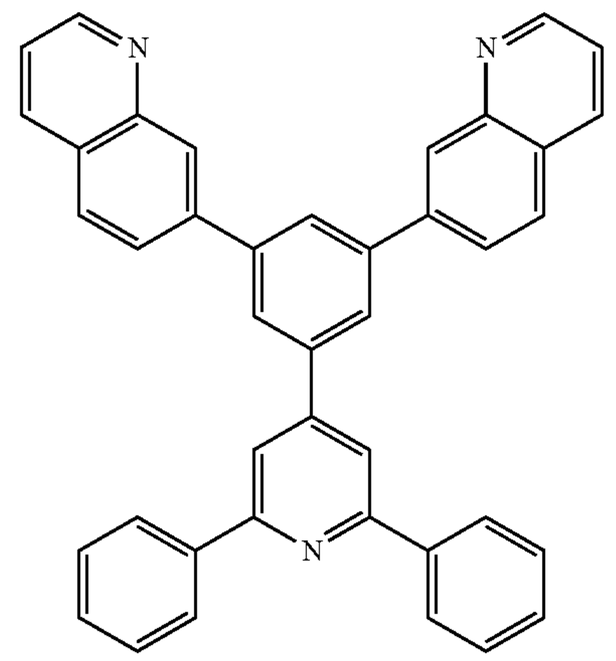

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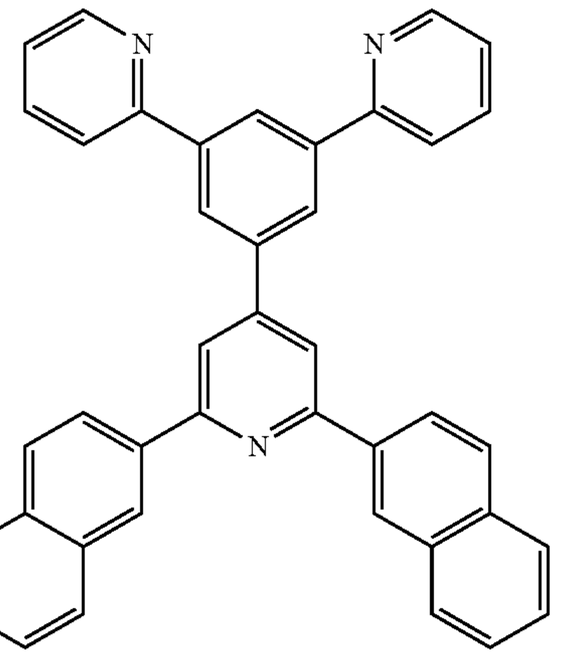

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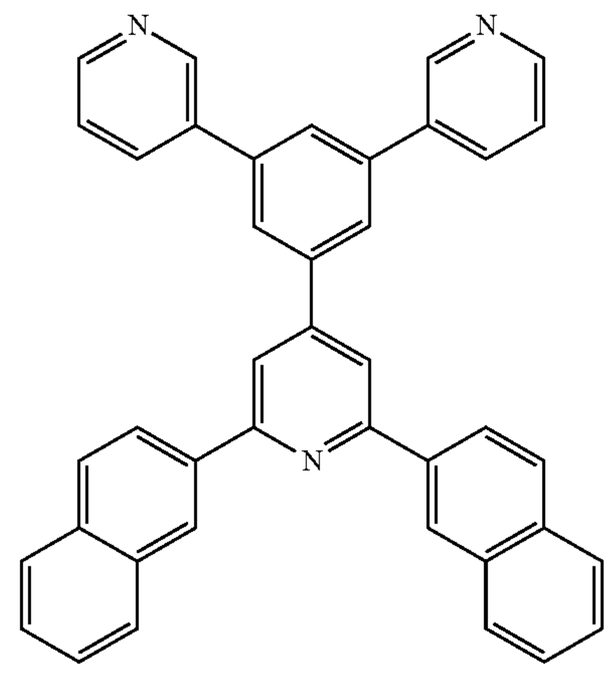

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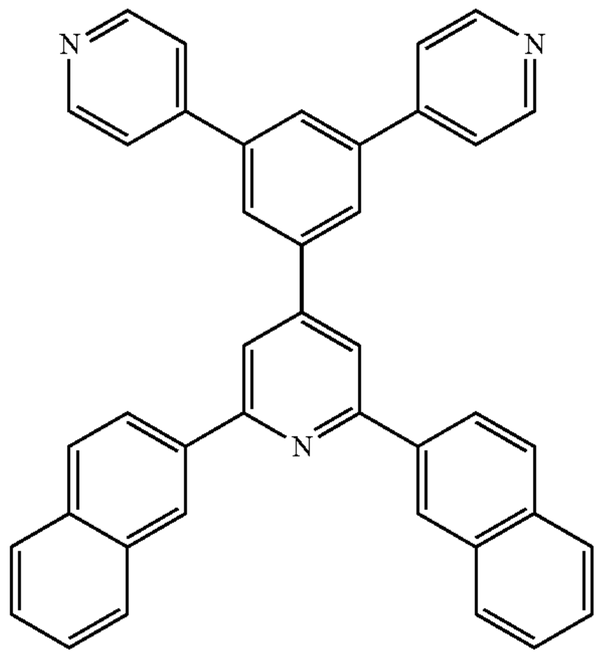

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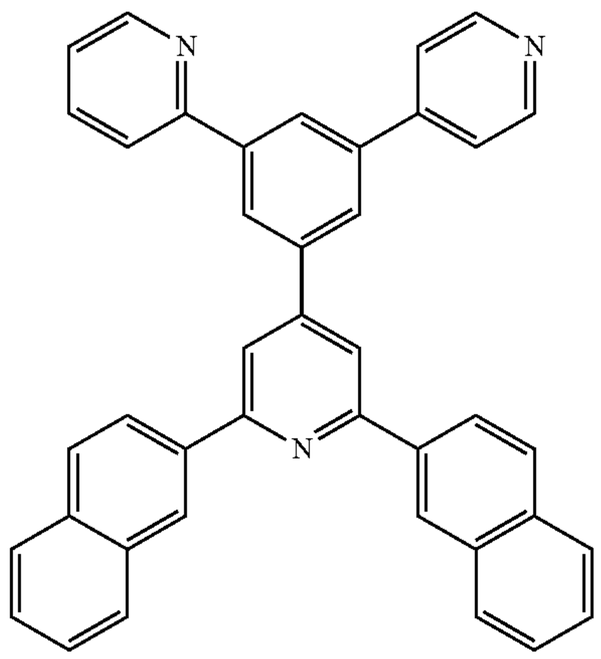

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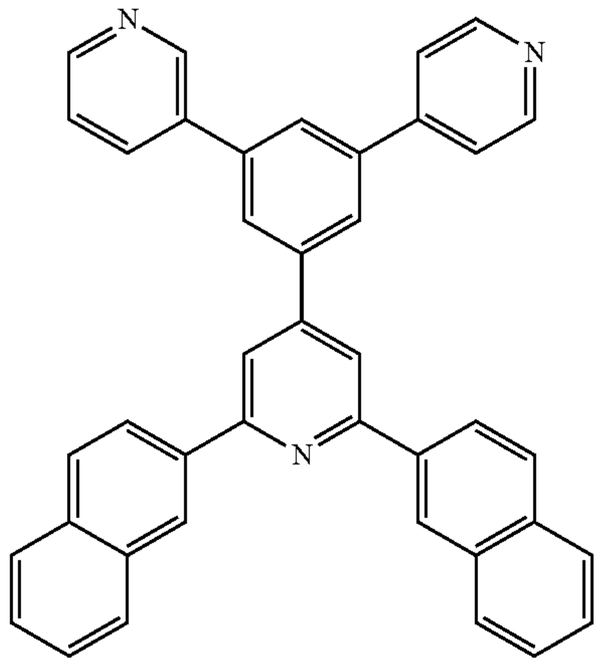

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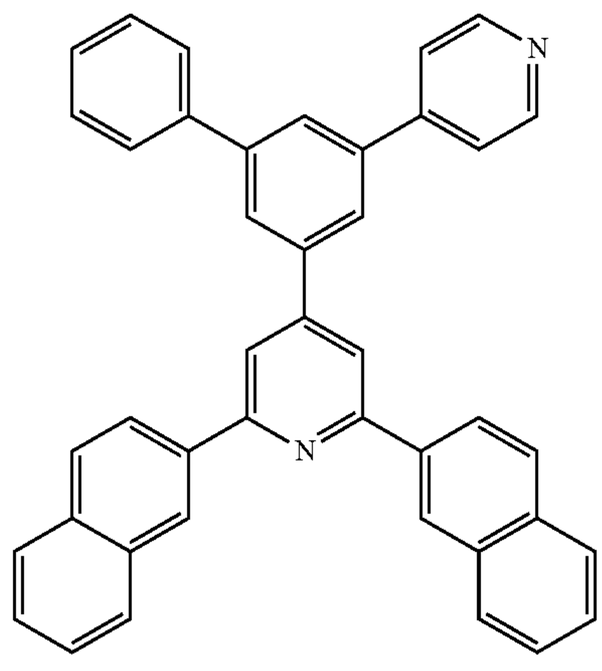

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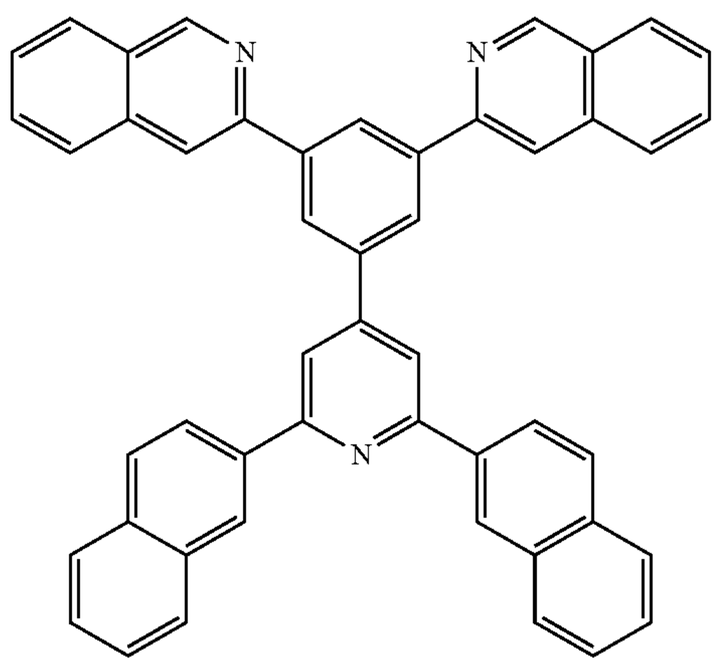

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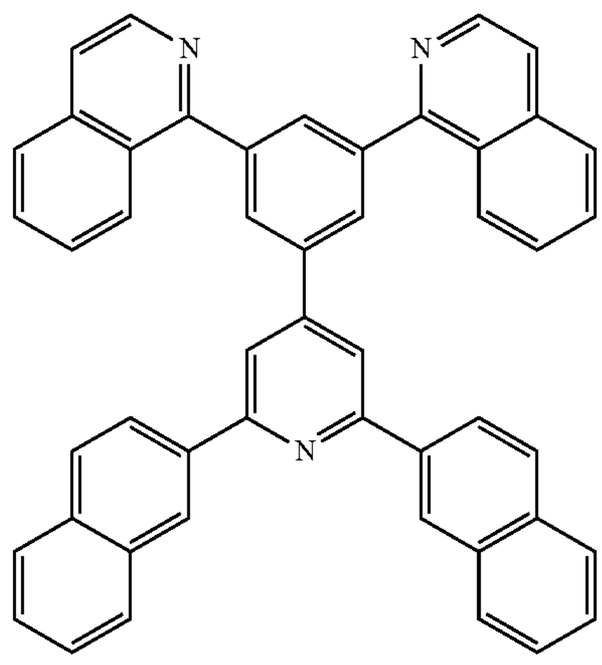

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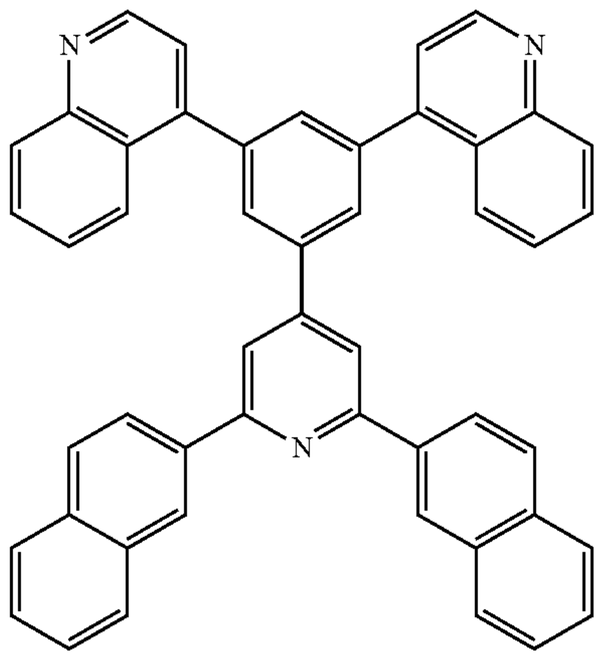

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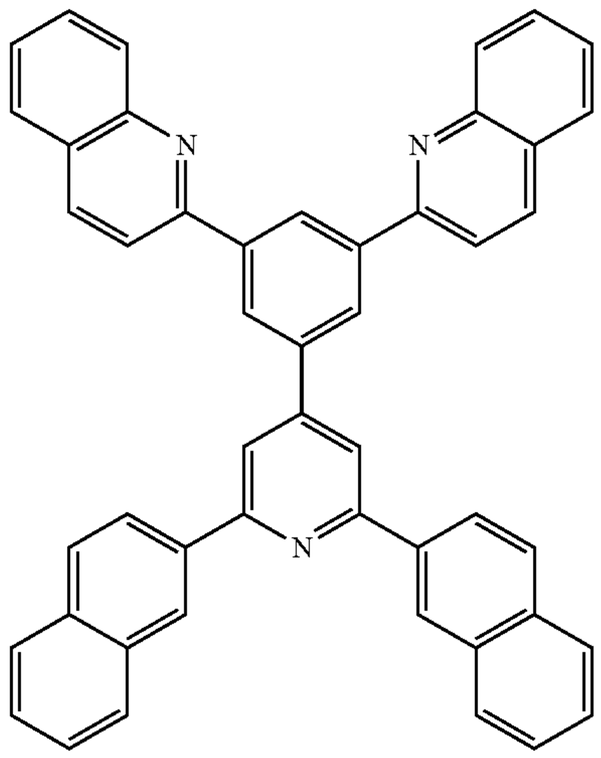

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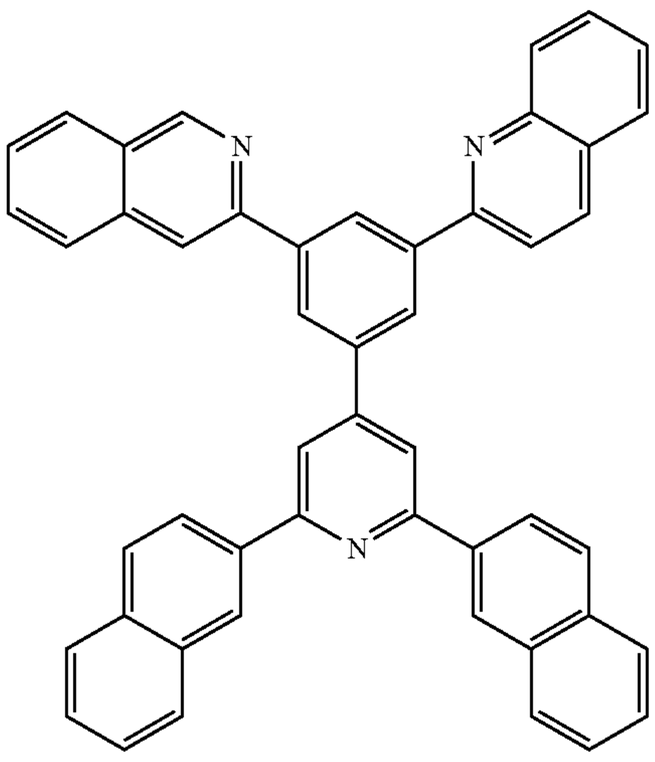

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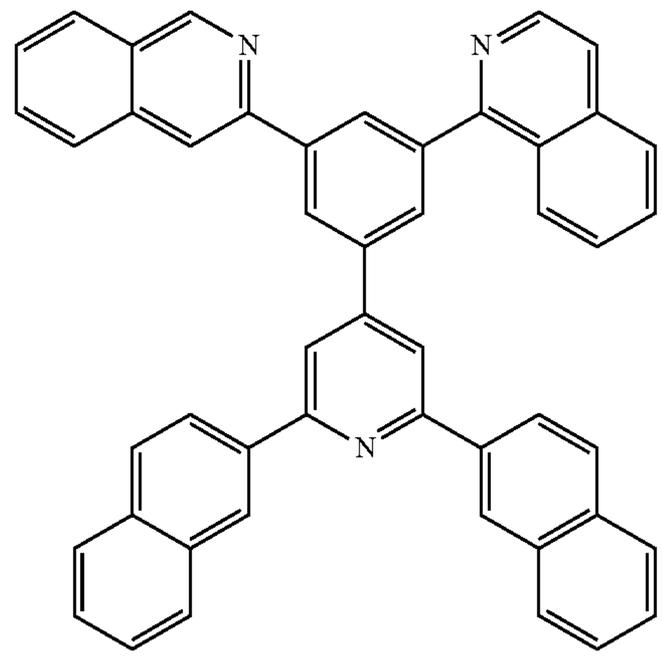

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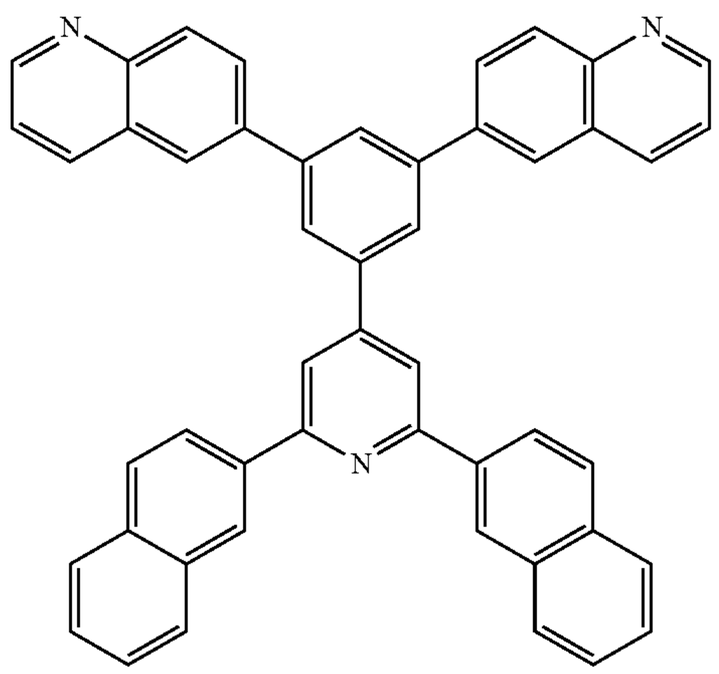

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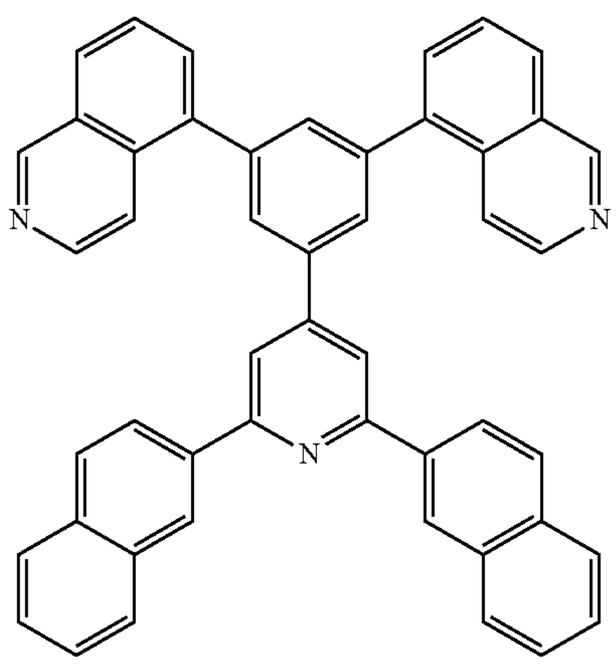

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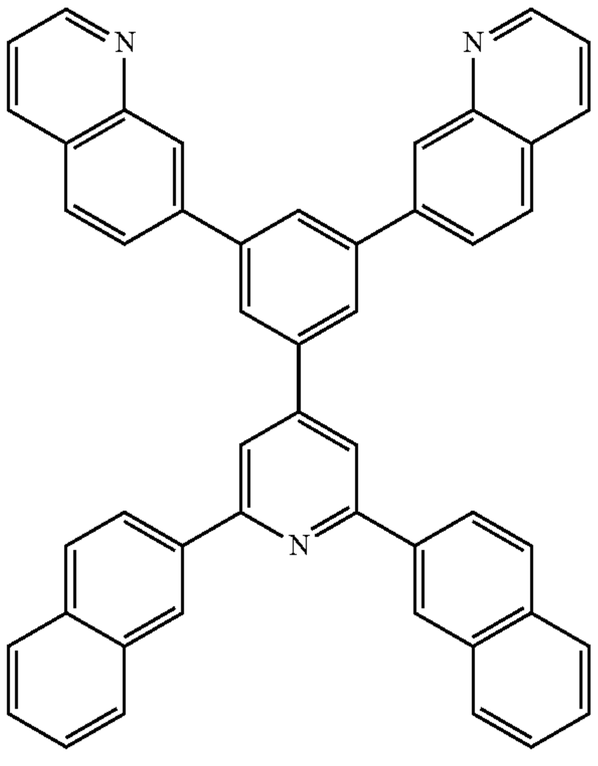

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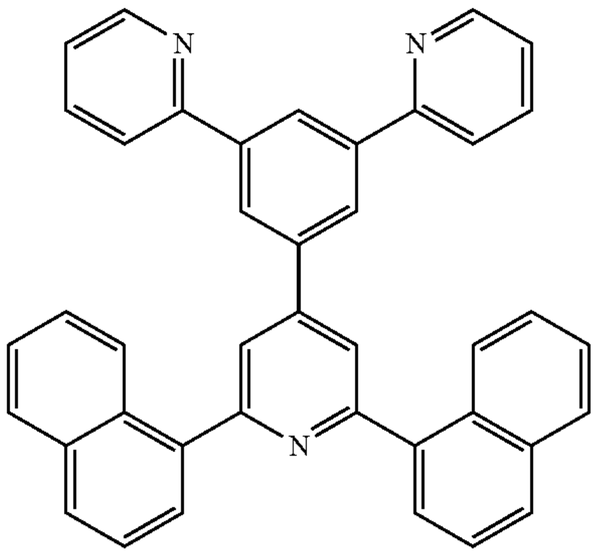

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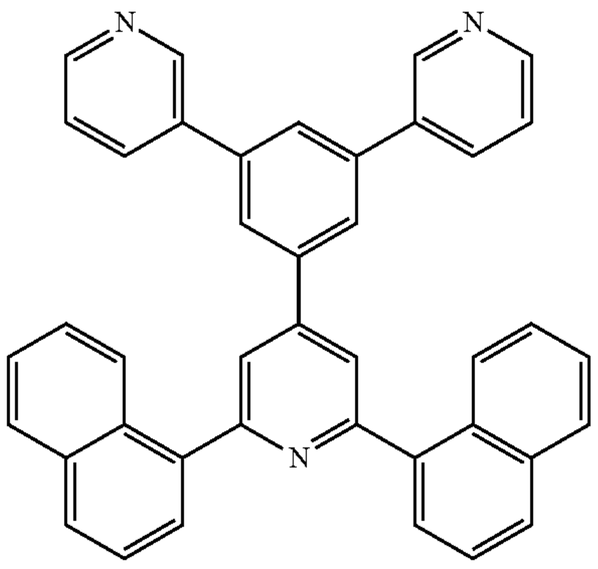

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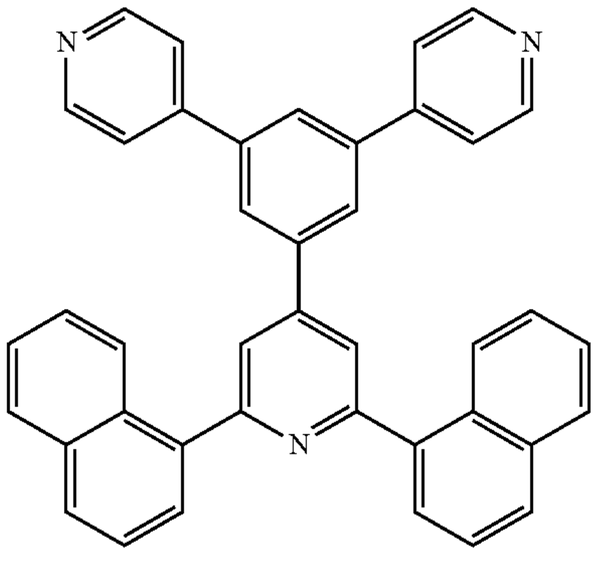

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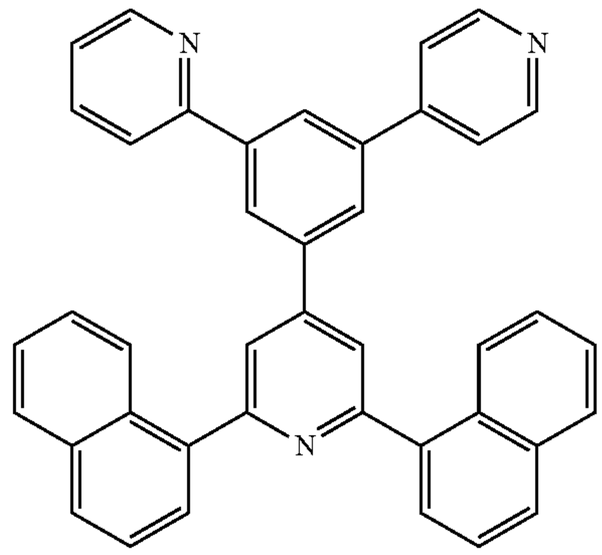

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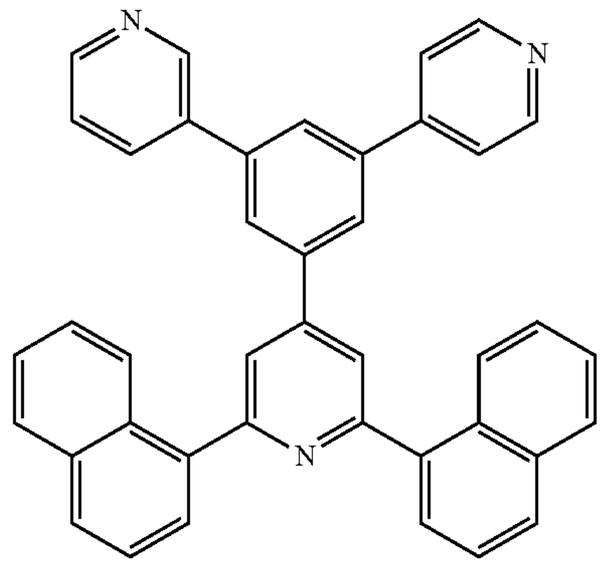

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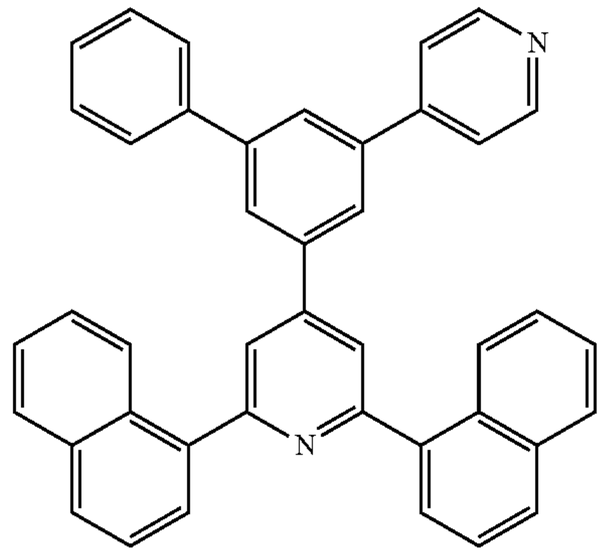

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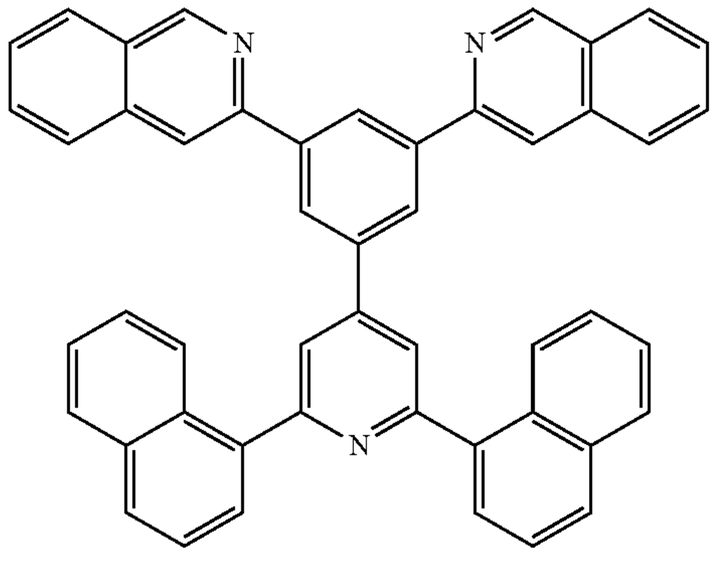

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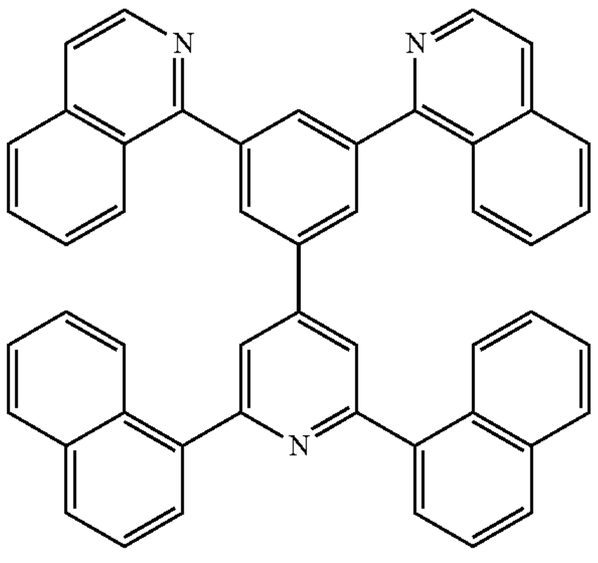

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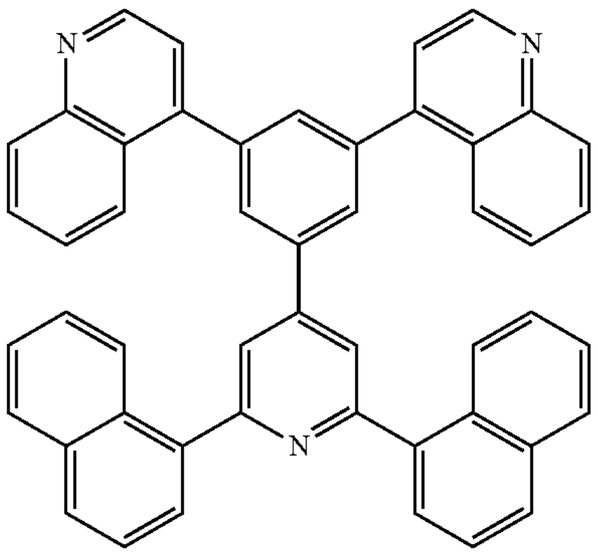

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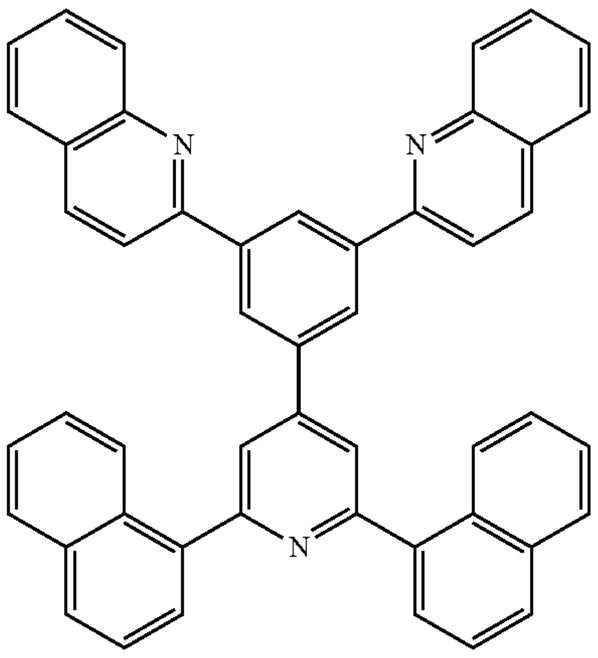

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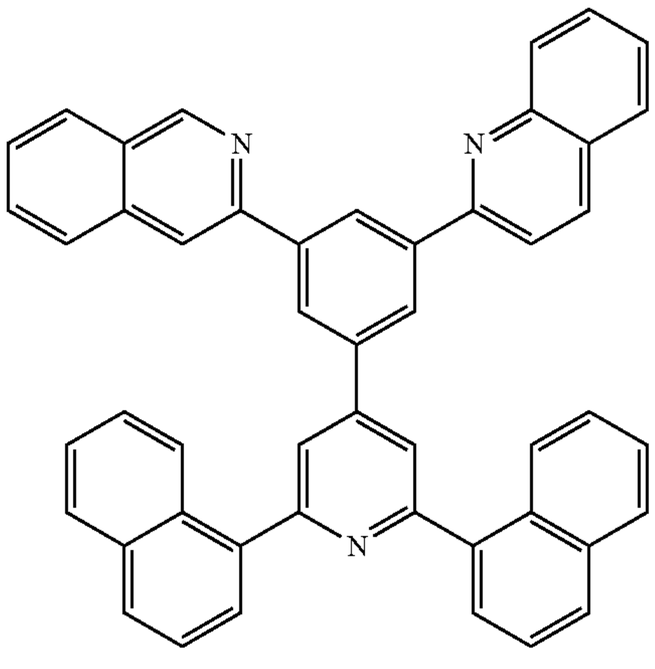

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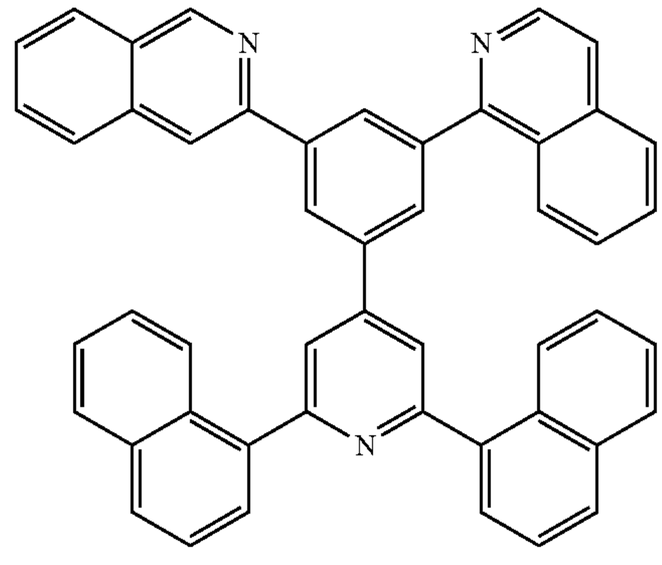

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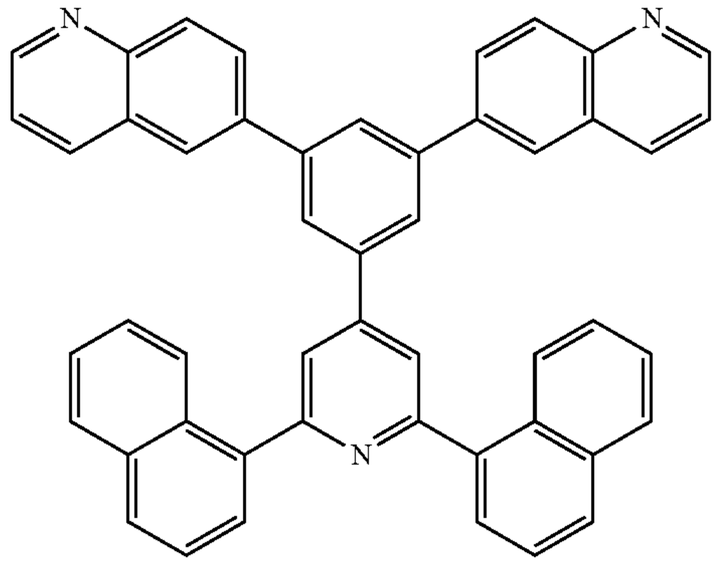

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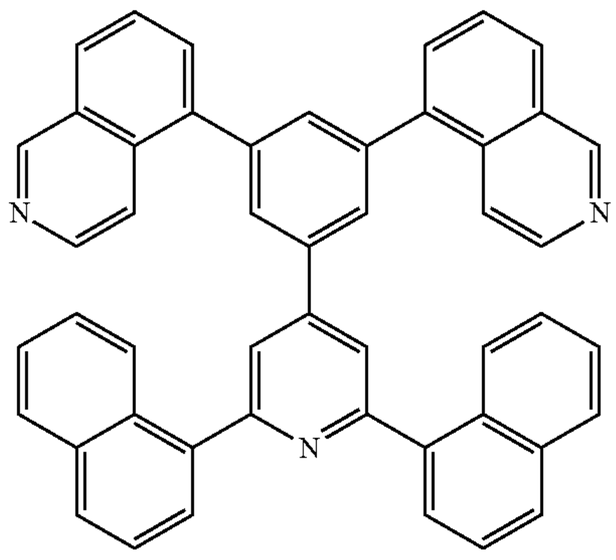

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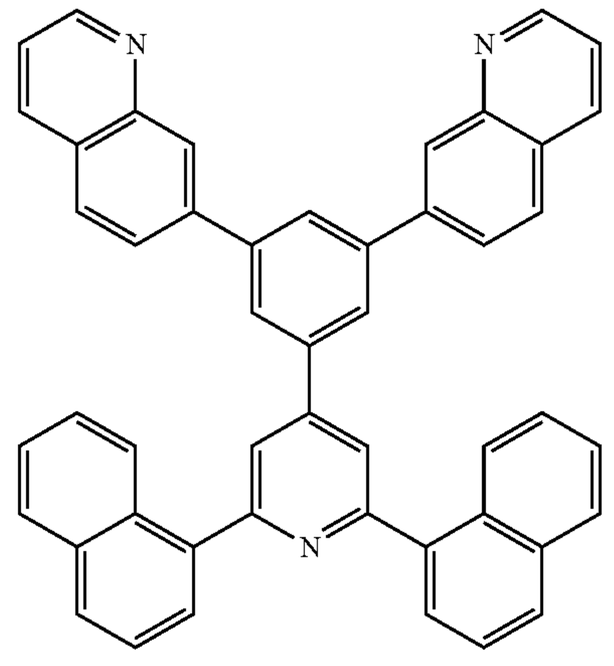

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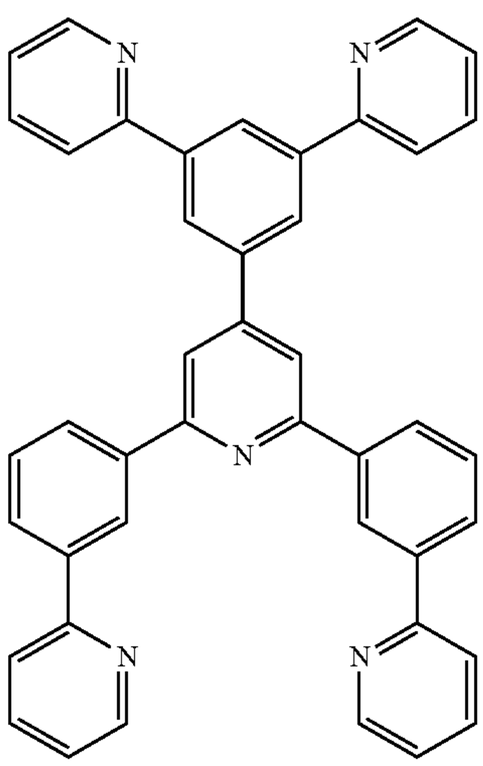

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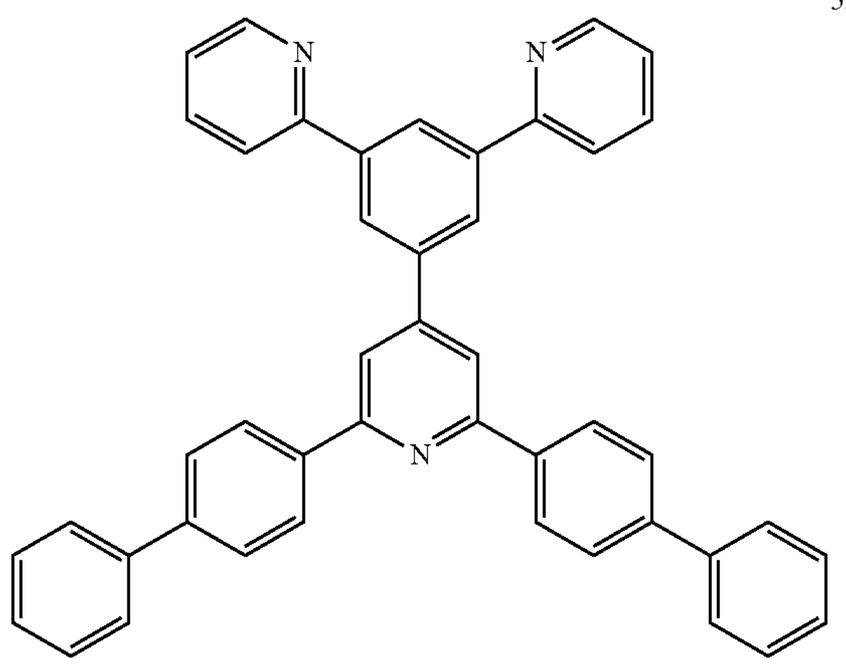

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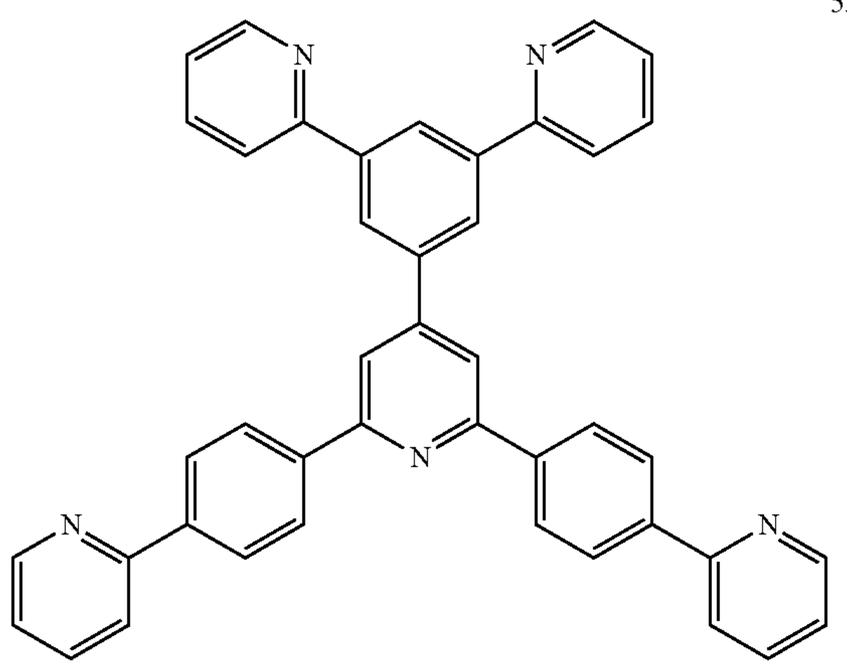

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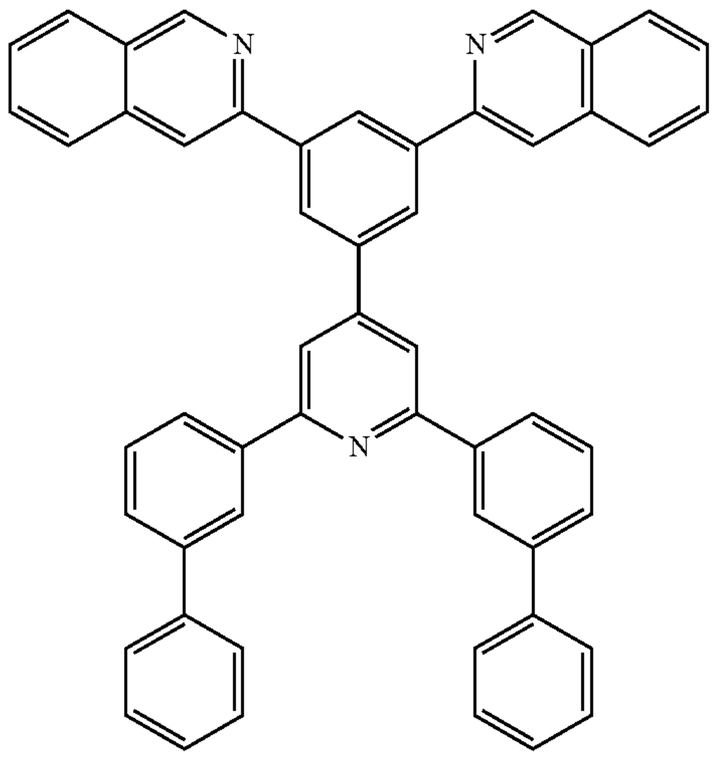

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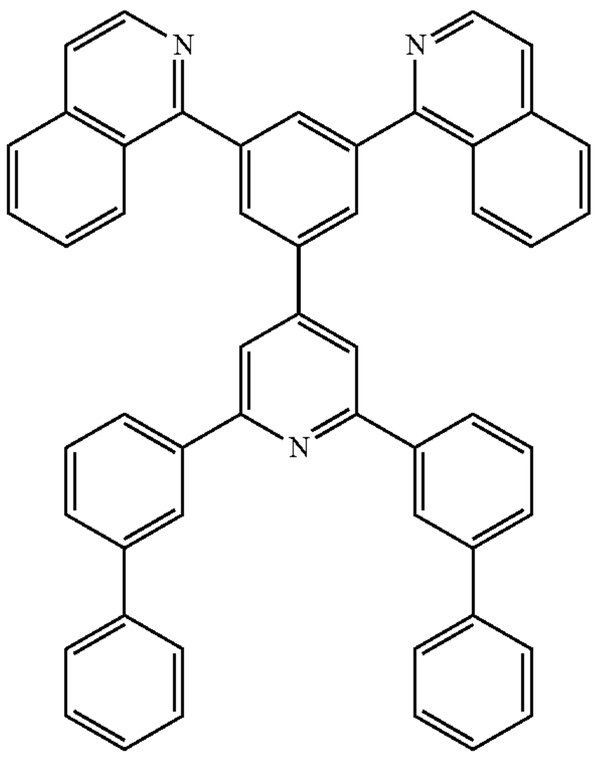

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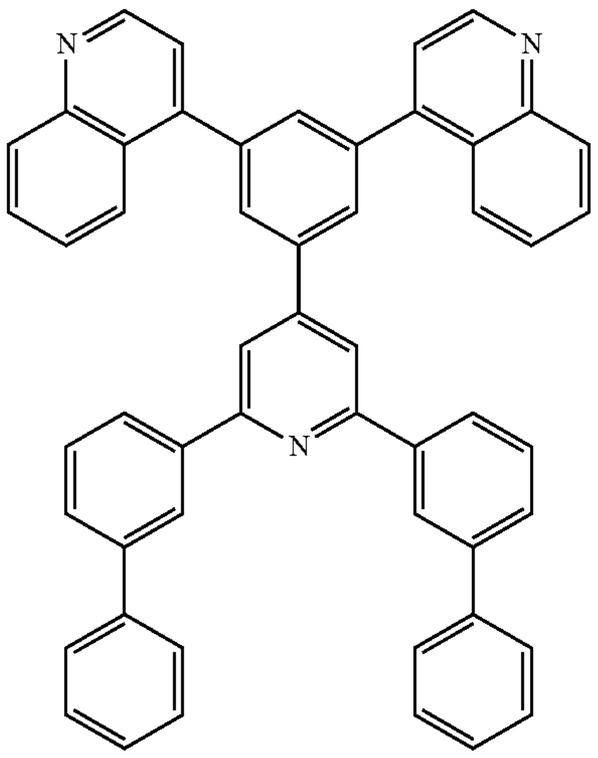

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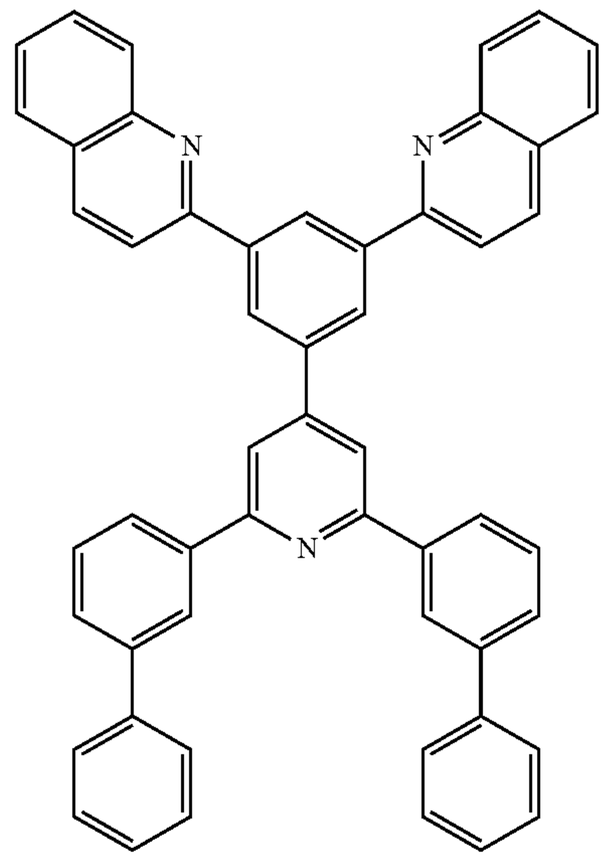

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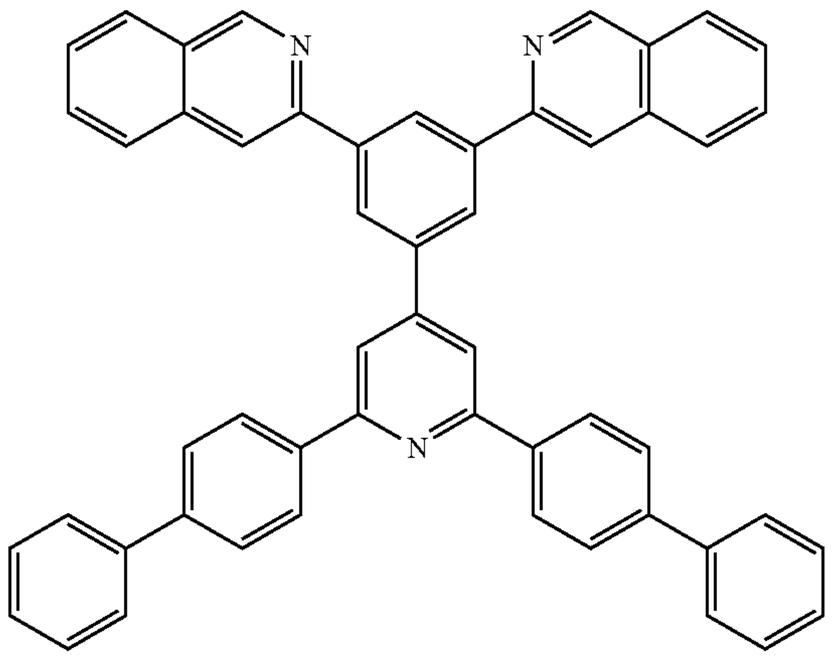

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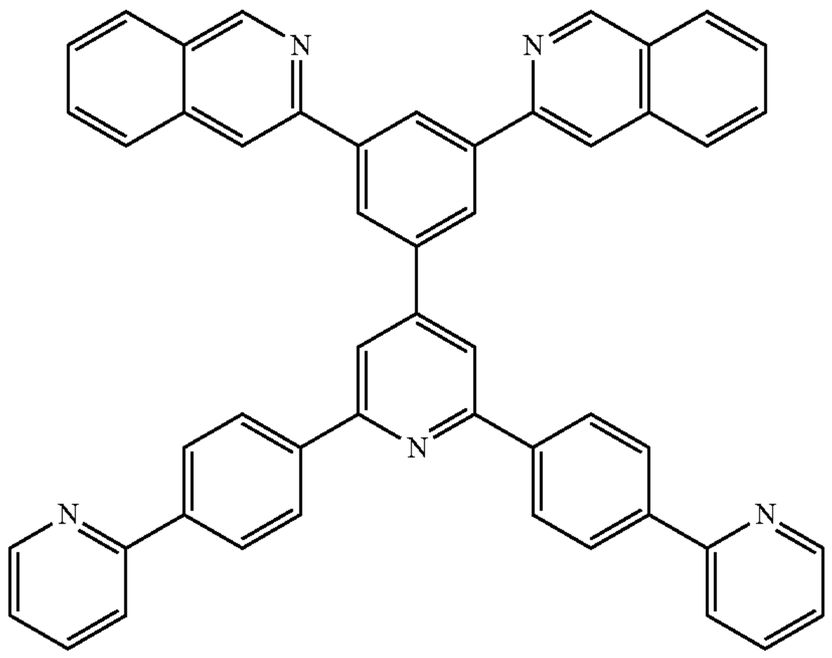

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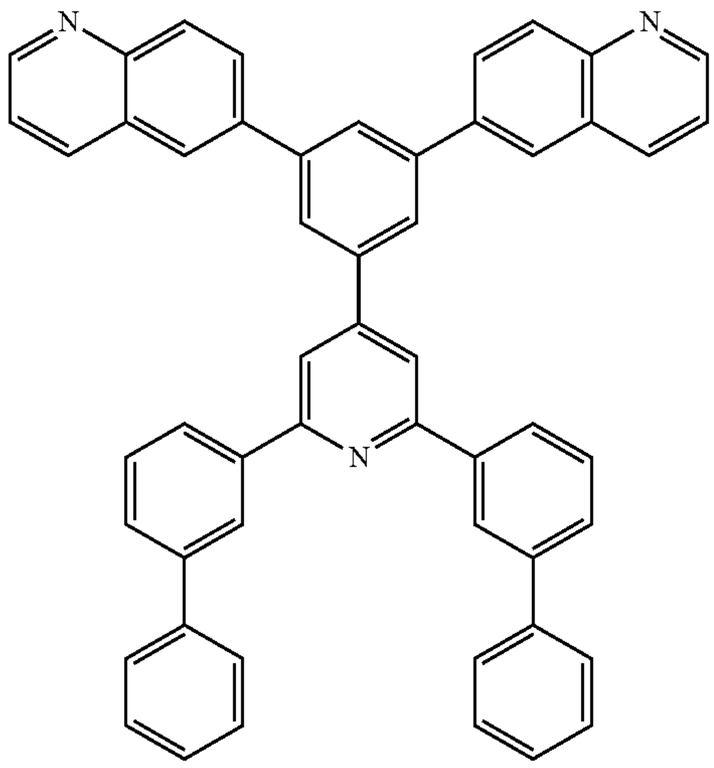

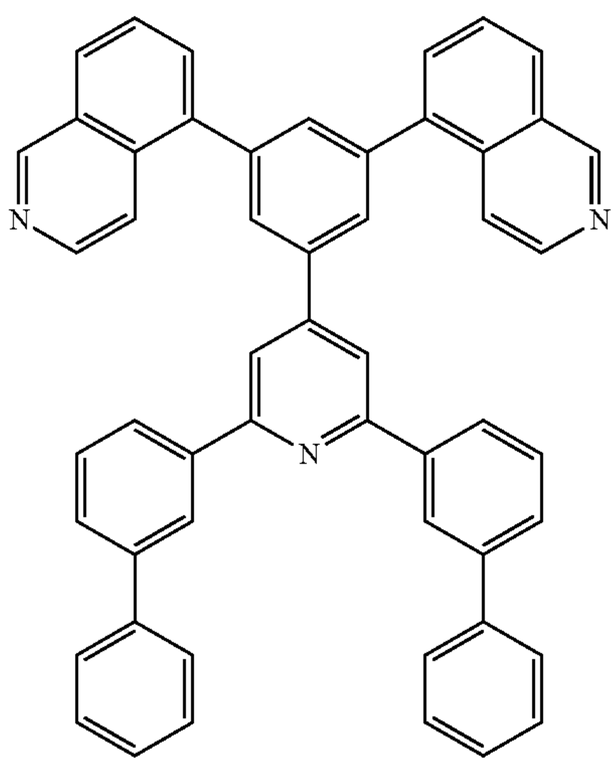

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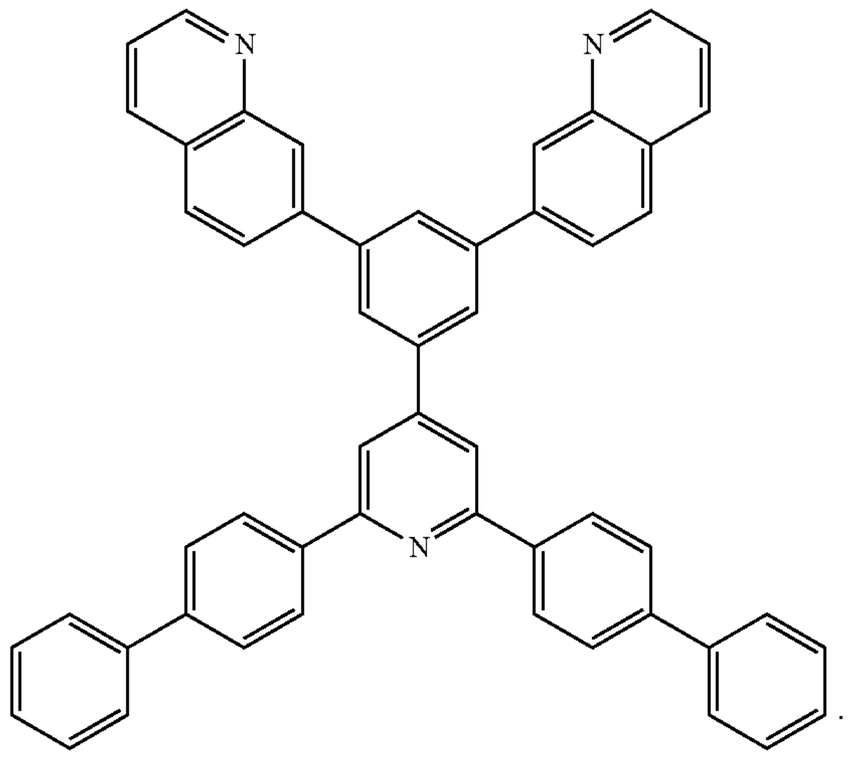

16. The organic light-emitting device of claim **1**, wherein the organic layer comprises:

an emission layer; and

an electron transport region between the second electrode and the emission layer, wherein the emission layer comprises the at least one first material represented by Formula 1; and

the electron transport region comprises the at least one second material represented by Formula 2.

17. The organic light-emitting device of claim **16**, wherein the electron transport region comprises an electron transport layer; and

the electron transport layer comprises the at least one second material represented by Formula 2.

18. The organic light-emitting device of claim **16**, wherein the electron transport region comprises a hole blocking layer; and

the hole blocking layer comprises the at least one second material represented by Formula 2.

19. The organic light-emitting device of claim **17**, wherein the emission layer and the electron transport layer are adjacent to each other.

20. The organic light-emitting device of claim **18**, wherein the emission layer and the hole blocking layer are adjacent to each other.

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